Chapter 5
HMS HABITAT PROVISIONS

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5.1 Introduction

This Chapter and the next (Chapter 6) identify and describe habitats, including essential fish habitat (EFH), for highly migratory species (HMS) covered by this FMP, on behalf of the Secretary of Commerce and in accordance with the Magnuson-Stevens Act. Chapter 5 describes how each of the regulatory requirements for the EFH provisions have been addressed and presents the distribution of HMS habitats within the jurisdictional area. Chapter 6 contains all of the mandatory elements for EFH identification, description and conservation, including explicit descriptions of the locations and characteristics of EFH for each managed species in text with referenced tables and maps. In addition, Chapter 6 considers threats to EFH from fishing activities and potential threats to EFH from non-fishing activities, and identifies options for the conservation and enhancement of HMS EFH that should be considered in the planning of projects that may adversely affect those habitats. These measures are representative of the conservation and enhancement measures that may be recommended by NMFS during consultation with Federal action agencies, as required by section 305(b) of the Magnuson-Stevens Act, on projects that may potentially impact HMS EFH. Specific conservation measures, however, will be developed on a case-by-case basis. NMFS' authority includes the direct management of activities associated with fishing for marine, estuarine and anadromous resources; NMFS' role in federal interagency consultations with regard to non-fishing threats is, more often than not, advisory. This document assumes no new authority or regulatory role for NMFS in the control of non-fishing activities beyond the statutory requirements to recommend measures to conserve living marine resources, including their habitats.

5.2 Regulatory Requirements

Section 303(a)(7) of the Magnuson-Stevens Act, 16 U.S.C. §§ 1801 *et seq*., as amended by the Sustainable Fisheries Act in 1996, requires that FMPs describe and identify EFH, minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat.

The Magnuson-Stevens Act provides the following definition: **"The term 'essential fish habitat' means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity."** (16 U.S.C. § 1802 (10)). The EFH regulations (at 50 C.F.R. 600 Subpart J) provide additional interpretation of the definition of essential fish habitat: **"'Waters' include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include aquatic areas historically used by fish where appropriate; 'substrate' includes sediment, hard bottom, structures underlying the waters, and associated biological communities; 'necessary' means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and 'spawning, breeding, feeding, or growth to maturity' covers a species' full life cycle."**

5.2.1 Description and Identification of EFH

The EFH regulations require that EFH be described and identified within the U.S. Exclusive Economic Zone (EEZ) for all life stages of each species in a fishery management unit. FMPs must describe EFH in text and tables that provide information on the biological requirements for each life history stage of the species. According to the EFH regulations, an initial inventory of available environmental and fisheries data sources should be undertaken to compile information necessary to describe and identify EFH and to identify major species-specific habitat data gaps. Available information should be evaluated through a hierarchical analysis based on: 1) presence/absence of the species in specific habitats; 2) habitat-related densities or relative abundances; 3) growth, reproduction, or survival rate comparisons between habitats; and 4) habitat-dependent production rates (quantified by habitat quantities, qualities and specific locations). This information should be interpreted with a risk-averse approach to ensure that adequate areas are protected as EFH for the managed species. In Chapter 6, habitats that satisfy the criteria in the Magnuson-Stevens Act and HMS EFH regulations have been identified and described as EFH; some additional habitats that have been identified as necessary for a sustainable fishery, but that lie outside the U.S. EEZ and therefore cannot be identified as EFH under the Magnuson-Stevens Act (e.g., the Gulf of Guinea off the African coast), have been highlighted as particularly important habitats to HMS, as suggested in the EFH regulations.

In order to fulfill the requirements of the EFH regulations and the Magnuson-Stevens Act, NMFS scientists at the Southeast Fisheries Science Center (SEFSC) and the Northeast Fisheries Science Center (NEFSC) conducted a complete review of the most recent information available. Their review covered the life histories of all HMS fishery species in the management unit, with an emphasis on the factors that influence distribution of the species. Much of the descriptive information for tunas and swordfish species is from the 1970s and 1980s, although each year the Standing Committee on Research and Science (SCRS) of ICCAT reviews and updates available information on species biology and stock structure. NMFS scientists made full use of the latest annual reports to ensure that the habitat information utilized was up-to-date. Dr. Jose Castro (SEFSC) recently completed a review of available information regarding the status of sharks worldwide for an upcoming United Nation Food and Agricultural Organization (FAO) publication. He and his assistants contributed information directly from the manuscript and undertook additional literature review to ensure that the information was the most current available. For all HMS, i.e., Atlantic tunas, swordfish and sharks, additional information was available in the form of fishery-independent sources (directed research investigations) and fishery-dependent sources (capture and bycatch reporting); although the location information is suitable for Geographic Information System (GIS) based spatial analysis of distributions, there is a general lack of accompanying environmental or habitat data with which to define habitat tolerances or preferences. All of the written accounts detailing HMS life history, distribution and habitat use were submitted to independent reviewers who provided comments on the draft manuscripts. These comments were considered and assessed by the scientific authors and included as appropriate. We are grateful to these reviewers for their excellent contribution to this and the following chapter, ensuring that the information is complete and up-to-date.

Chapters 5 and 6 contain all of the required provisions as specified in the EFH regulations, covering all life stages of the species managed under this FMP for which information is available.

5.2.2 Fishing Activities That May Adversely Affect EFH

The EFH regulations and the Magnuson-Stevens Act require the fishery management councils (Councils) and NMFS, on behalf of the Secretary of Commerce, to minimize adverse effects on EFH from fishing activities to the extent practicable. Adverse effects from fishing may include physical, chemical, or biological alterations of the substrate, and loss of or injury to benthic organisms, prey species and their habitat, and other components of the ecosystem. Based on an assessment of the potential adverse effects of all fishing equipment types used within an area designated EFH, the Council should act if there is evidence that a fishing practice is having an identifiable adverse effect on the EFH.

In order to determine whether HMS fishing causes adverse impacts on EFH, an assessment was made of the gears and practices as described in the proposed gear rule (63 FR 30455, June 4, 1998). Impacts of HMS and non-HMS fishing gears and practices were analyzed by examining published literature and anecdotal evidence of potential impacts or comparable impacts from other fisheries (Section 6.6). Based on this initial assessment the fishing methods of the HMS fisheries apparently have limited impact on HMS EFH. There is the possibility, however, that other (non-HMS) fisheries may adversely impact HMS EFH, although the degree of that impact is impossible to ascertain from the data currently available. This question needs to be more closely examined and addressed through coordination with other fishery management authorities. No new management measures, and therefore no regulations, are proposed in these habitat chapters, although the evaluation of fishing impacts on EFH does provide additional support for the implement-ation of time/area closures that would also serve as a precautionary measure to maintain the biological characteristics of HMS (bluefin tuna) EFH. At this time there is no evidence that HMS fishing practices are causing adverse impacts on the EFH of HMS, although conservation recommendations are included to mitigate the possible effects of fishing practices listed in Section 6.6. NMFS is aware that other actions may be required in the future as a greater understanding of the impacts of fishing gear on fish habitat is gained. Future management measures could include fishing gear or practice restrictions, additional time/area closures, harvest limits on the take of species that provide structural habitat or of prey species. Areas that are currently closed to fishing should be used as experimental control areas to research the effects of fishing gears on habitat.

5.2.3 Non-Fishing Activities That May Adversely Affect EFH and Respective Conservation Measures

Section 600.815 (a)(5) of the EFH regulations requires that FMPs identify non-fishing related activities that may adversely affect EFH of managed species, either quantitatively or qualitatively, or both. In addition, Section 600.815 (a)(7) requires that FMPs recommend conservation measures describing options to avoid, minimize, or compensate for the adverse effects identified.

Broad categories of activities that may adversely affect HMS EFH include, but are not limited to: 1) actions that physically alter structural components or substrate, e.g., dredging, filling, excavations, water diversions, impoundments and other hydrologic modifications; 2) actions that result in changes in habitat quality, e.g., point source discharges, activities that contribute to non-point-source pollution and increased sedimentation, introduction of potentially hazardous materials, or activities that diminish or disrupt the functions of EFH. If these actions are persistent or intense enough they can result in major changes in habitat quantity as well as quality, conversion of habitats, or in complete abandonment of habitats by some species.

As required under the EFH regulations, Chapter 6 identifies activities having the potential to adversely affect HMS EFH. In many cases these activities are regulated under particular statutory authorities. As long as they are regulated within those guidelines, their potential to adversely affect EFH may be reduced, although not necessarily eliminated. Many of the standards that are used to regulate these activities are based on human health needs and do not consider long-term impacts on fish and fish habitats. Additionally, if the activity fails to meet or is operated outside its permitted standards, it may adversely affect EFH. The EFH regulations require NMFS and the Councils to identify actions with the **potential** (emphasis added) to adversely affect EFH, including its biological, chemical and physical characteristics. The EFH regulations also recommend the examination of cumulative impacts on EFH. It is possible that many permitted actions operating within their regulatory bounds may cause adverse impacts on EFH. Chapter 6 lists a broad range of activities to ensure that their potential to adversely affect HMS EFH will be adequately considered.

The review of HMS habitat use undertaken for Chapters 5 and 6 identified both benthic and water column habitats in coastal, estuarine and offshore areas as EFH, although in many cases the particular habitat characteristics that control species habitat use are not clearly identified. Many of these factors seem to be related to water quality, e.g., temperature, salinity, dissolved oxygen. Therefore, water quality degradation is a primary focus in Section 6.6. When analyzing the impacts that water quality changes can have on HMS EFH, it is important to examine all habitats. Although EFH for HMS includes offshore areas, these distant habitats are affected by actions that occur in coastal habitats (both terrestrial and aquatic) and adjacent estuaries. Many of the HMS aggregate over submarine canyons or along river plumes; these physiographic features can serve as conduits for currents moving from inshore out across the continental shelf and slope, redistributing contaminants from the nearshore realm to offshore habitats. Until the precise zones of influence from various river and coastal discharges can be delineated, a precautionary view should be taken in order to protect the integrity of HMS EFH and the sustainability of the HMS fisheries.

In addition to identifying activities having the potential to adversely affect EFH, the Magnuson-Stevens Act and the EFH regulations require the inclusion of measures to conserve and enhance EFH. Each activity discussed in Chapter 6 is followed by conservation measures to avoid, minimize or mitigate its adverse effects on EFH. These include examples of both general and specific conservation measures that might be appropriate for NMFS to recommend when consulting on similar proposed activities. In some cases the measures are based on site-specific activities, in others the recommendations represent broad policy-type

guidelines. During EFH consultations NMFS will evaluate each project based on its merits and potential threat to EFH, and the appropriate conservation measures will be assessed at that time. The Federal action agency with the statutory authority to regulate the proposed action must weigh all comments and decide on the appropriate action, modifications or mitigation before proceeding with a project. The conservation measures included in this FMP provide examples of NMFS' recommendations that potentially could be made regarding particular projects. They are intended to assist Federal and state agencies and other entities during the planning process when minimization of adverse impacts on EFH can most effectively be incorporated into project designs
and goals.

Maps geographically depicting threats to EFH should be included in an FMP. At the present time, however, the information for producing accurate maps depicting threats to HMS EFH is not available. The use of GIS for mapping EFH distributions will allow the addition of this information as it becomes available.

5.2.4 Cumulative Impacts Analysis

The EFH regulations require that to the extent feasible and practicable FMPs should analyze how fishing and non-fishing activities influence habitat function on an ecosystem or watershed scale. At this time the technology is not available to provide a site-specific analysis of cumulative impacts for each area that has been identified as EFH for HMS, although the use of GIS technology to map EFH for this FMP will facilitate the investigation of cumulative impacts in the future. A discussion of specific habitat loss arising from cumulative impacts is included in Section 6.6.3 to illustrate the types of effects that will be investigated in the future when the techniques and data become available.

5.2.5 Habitat Areas of Particular Concern

The EFH regulations suggest that FMPs should identify Habitat Areas of Particular Concern (HAPC) within EFH for habitats that satisfy the criteria of being sensitive or vulnerable to environmental stresses, are rare, or are particularly important ecologically.

Because of the general lack of information regarding HMS habitat associations, it is possible at this time to identify only one HAPC for the HMS managed under this FMP (for sandbar shark - refer to Section 6.3). As information becomes available in the future, it may become possible to identify additional HACPs within HMS EFH.

5.2.6 Research and Information Needs

The EFH regulations suggest that FMPs should contain recommendations, preferably in priority order, for research efforts that have been identified as necessary for carrying out the EFH management mandate.

Chapter 6 contains a listing of research and information needs that should be addressed in order to improve the ability to conserve and manage habitat concerns under the EFH mandate. These efforts vary from the gathering of additional information from diverse sources in order to better map the distributions of EFH, to long range research projects that will provide additional life history information for use in better defining the environmental parameters that influence the distribution of the HMS.

5.3 Habitat Goals

Information presented in this chapter is consistent with the goals of habitat conservation. The chapter further proposes the following guidance for future NMFS actions regarding the management of HMS fishery resources:

- Recognizing that all species are dependent on the quantity and quality of their essential habitats, it is the goal of the NMFS Highly Migratory Species Management Division to:

    - Conserve, restore and improve habitats upon which commercial and recreational marine fisheries depend, to increase their extent, and to improve their productive capacity for the benefit of present and future generations.

This policy is supported by two general objectives:

1. Maintain the current quantity and productive capacity of habitats that support commercial and recreational fisheries, through development of a better understanding of the dynamics of habitat that influence biological productivity, and the pursuit of a hierarchical policy of avoidance, minimization and compensatory mitigation for actions that cause adverse effects on essential fish habitats.

2. Restore, rehabilitate or enhance the productive capacity of degraded habitats to increase fishery productivity for the benefit of the resource and the Nation.

5.4 HMS Habitat Types and Distributions

The highly migratory species included in this FMP (tunas, swordfish, and sharks) traverse large expanses of the world's oceans, straddling jurisdictional boundaries. Although many of the species frequent other oceans of the world, the Magnuson-Stevens Act only authorizes the description and identification of EFH in Federal, state or territorial waters, including areas of the U.S. Caribbean, the Gulf of Mexico and the Atlantic coast of the United States to the seaward limit of the U.S. EEZ. These areas are connected by currents and water patterns that influence the occurrence of HMS at particular times of the year. On the largest scale, the North and

South Equatorial currents bathe the U.S. Caribbean islands. The North Equatorial Current continues through the Caribbean Basin to enter the Gulf of Mexico through the Yucatan Straits. The current continues through the Florida Straits to join the other water masses (including the Antilles Current) to form the Gulf Stream along the eastern coast of the United States. Variations in flow capacities of the Florida Straits and the Yucatan Straits produce the Loop Current, the major hydrographic feature of the Gulf of Mexico. These water movements in large part influence the distributions of the pelagic life stages of HMS.

Analysis of the life histories and distribution of the HMS managed under this FMP led to the identification of various habitats essential to the species. These have been highlighted whenever possible as EFH in the text descriptions found in Section 6.3. Tuna and swordfish distributions are most frequently associated with hydrographic features such as density fronts between different water masses. The scales of these features vary. For example, the river plume of the Mississippi River extends for miles into the Gulf of Mexico and is a fairly predictable feature, depending on the season. Fronts that set up over the De Soto Canyon in the Gulf of Mexico, or over the Charleston Bump or the Baltimore Canyon in the mid-Atlantic, may be of a much smaller scale. The locations of many fronts or frontal features are statistically consistent within broad geographic boundaries. These locations are influenced by riverine inputs, movement of water masses, and the presence of topographic structures underlying the water column, thereby influencing the habitat of HMS.

In determining EFH for HMS, consideration has been given to habitat associations for all life stages. Although they typically range throughout open ocean waters, many HMS also move inshore, including coastal estuaries, at some time during their life cycles. For example, Atlantic sharks are broadly distributed as adults but have been found to utilize specific estuaries and shallow coastal areas during pupping. Typically, the pups (neonates) remain in these same areas throughout their early life stages, which may vary from a few to many months. Many of these estuaries and shallow coastal areas used for pupping have been characterized only in general terms (e.g., salinity, temperature and/or season). Associations with particular bottom types are undefined, and this lack of information has been identified as an important research need (Section 6.7).

Because of the seasonal use of these habitats in addition to open ocean habitats, inshore areas and estuaries are described in terms of distribution, size, depth, freshwater inflow and habitat types (e.g., bottom types) available. As additional information is accumulated, this section will be expanded to more fully characterize the links between the managed species and specific habitat characteristics. The following sections describe the distribution of the habitats that are utilized by HMS, including those that are considered to be EFH. They include descriptions of the continental shelf/slope features and the dominant current patterns in-so-far as they may influence the existence and persistence of hydrographic fronts. Much of the information originally appeared inother documents and references(Appeldoorn and Meyers, 1993; Field *et al.* 1991, MMS, 1992; 1996, NOAA, 1992; 1996; 1997a; 1997b; and 1997c). Original sources are cited in these.

5.4.1 Atlantic

For identification of EFH for HMS under the Magnuson-Stevens Act, the Atlantic region of U.S. Federal jurisdiction spans the area between the Canadian border in the north and the Dry Tortugas in the south. It includes a diverse spectrum of aquatic species of commercial, recreational, and ecological importance. The distribution of marine species along the Atlantic seaboard is strongly affected by the cold Labrador Current in the north part, the warm Gulf Stream in the middle and south portions of the region, and generally by the combination of high summer and low winter temperatures.

For many species Cape Hatteras forms a strong zoogeographic boundary between the mid- and south Atlantic areas, while the Cape Cod/Nantucket Island area is a somewhat weaker zoogeographic boundary in the north. Considering the region as a whole, there are four fairly distinct biological regimes:

1. **Arcadian/Scotian Province** - from the Canadian border (jurisdictionally) to just south of Cape Cod (north Atlantic);

2. **Virginian Transition Province** - from Cape Cod to Cape Hatteras;

3. **Carolinian Province** - Cape Hatteras to just south of Cape Canaveral; and

4. **Floridian/Caribbean Province** - just north of Miami to the Dry Tortugas.

For the purposes of this chapter the Atlantic region is divided into three zones - north Atlantic, mid-Atlantic, and south Atlantic - for general descriptions of habitats, combining regimes 3 and 4 above. However, species distributions and ecological roles are influenced by the larger scale environments (province). The boundaries between these zones are fluid and do not limit either the movement of the HMS or the water masses that flow through each region. All of these provinces have resident and migratory species that make up the complex fish assemblages. The mid-Atlantic area from Cape Cod to Cape Hatteras represents a transition zone between northern cold-temperate waters of the north and the warm-temperate waters to the south. Water temperatures in the mid-Atlantic vary greatly by season. Consequently, many of the fish species of importance in the mid-Atlantic area, including HMS, migrate seasonally, whereas the major species in the other three areas are typically resident throughout the year(MMS, 1992; 1996).

Continental Shelf/Slope Features
(Material in this section is largely a summary of information in MMS, 1992; 1996. Original sources of information are referenced in those documents)

***North Atlantic Shelf Features*:** The circulation patterns of the Gulf of Maine and Georges Bank dominate the oceanographic regime of the northeast Atlantic shelf. The Gulf of Maine is a deep indentation in the continental shelf with irregular bottom topography. Its bottom consists of three major basins and many smaller ones separated by numerous ridges and ledges. It is a semi-enclosed sea, with Nova Scotia as its north and east boundary and the northeast U.S. coast as its west boundary. Georges and Browns Banks significantly separate the Gulf of Maine from the Atlantic Ocean.

Georges Bank is a large, relatively shallow topographic high that lies southeast of the Gulf of Maine, its seaward edge comprising part of the shelf break in the north Atlantic. The Bank is consistently one of the most productive habitats for plankton in the world. The tidal and oceanographic current regimes in the area and Georges Bank's proximity to deep slope water allow upwelling events to occur that transport nutrient-rich deep water to the shallow, euphotic areas of the bank. This provides increased primary productivity that benefits higher trophic level fish and shellfish species. On the seaward side, Georges Bank is incised by numerous submarine canyons. The outcroppings and hardened sediments of the canyons provide increased attachment substrate for deeper-water epifaunal organisms (animals attached to the substrate) and allow complex faunal communities to form.

From the Scotian Shelf in the north, past Georges Bank and through the Mid-Atlantic Bight, a shelf-slope front exists. This hydrographic boundary separates the fresher, colder, and more homogeneous waters of the shelf and the horizontally stratified, warmer, and more saline waters of the continental slope. The shelf-slope front may act as a barrier to shelf-slope transfer of water mass and momentum.

From Nova Scotia to Cape Hatteras, 26 large valleys which originate on the shelf cut into the seafloor downward across the continental slope and rise. The current regimes in these submarine canyons promote significant biological productivity and diversity. Tidal oscillations on the shelf, combined with the intermittent influence of Gulf Stream warm core rings on the slope, dominate currents and influence sediment transport in the canyons. The canyon topography directs the mean shelf current below 100 meters (m) (328 feet) into the canyon rather than along the shelf break. Peak currents occur near the canyon heads and flow down the canyon, while currents at intermediate depths flow up the canyon. These patterns suggest a circulation that may trap sediments in the canyon heads and produce conditions conducive to front development. HMS are known to aggregate in the areas where these fronts form, most likely as productive feeding grounds.

***Mid-Atlantic Shelf Features*:** The mid-Atlantic region is between the colder, arctically influenced environments to the north and the warm, sub-tropical systems to the south. This area reflects a transition zone between the glacial till, rocky shores and steep gradients of the New England states and the wide, gently sloping geology of the coastal plains of the southeast United States. The mid-Atlantic is a highly diverse, often seasonally-utilized zone for many aquatic and terrestrial species. A major biogeographic boundary for marine organisms on the continental shelf occurs at Cape Hatteras where the Gulf Stream turns eastward, separating the temperate and tropical provinces. A sharp faunal break is less obvious on the slope, although this area does appear to be a region of rapid faunal change.

The mid-Atlantic shelf is relatively flat, but there is a ridge-and-swale (hill-and-valley) topography that may be a result of present oceanographic conditions or remnant barrier beaches. The shelf typically is composed of a thin surface layer of poorly-sorted shell and medium-to-coarse grained sand that overlays clay sediments. In general, the surface sediments grade from medium-grained sands inshore to finer sediments at the shelf break. Coarse-grained sediments generally support large quantities of animals, including many sessile forms. Fine-grained sediments usually contain a depauperate fauna, and attached organisms are uncommon. Within the Mid-Atlantic Bight, the quantity of fauna decreases markedly from north to south and from shallow to deep water.

Offshore in the east United States, the six major submarine canyons - Block, Hudson, Wilmington, Baltimore, Washington, and Norfolk Canyons - occur within 150 km of shore. They begin in waters of little more than 100 to 200 m (325 to 650 feet) and descend to 2,000 m (6500 feet). Numerous smaller submarine canyons, V-shaped valleys that resemble terrestrial canyons of fluvial origin, cut into the continental slope along the Atlantic coast. These canyons become less rugged and numerous to the south with the last significant one, Norfolk Canyon, occurring off Chesapeake Bay.

Canyon topography tends to be rugged and diverse, with numerous outcrops providing a greater amount of substrate for faunal attachment than is typically found along the remainder of the continental margin. Submarine canyons also appear to function like terrestrial watersheds, concentrating water, sediments, and dissolved and particulate nutrients which flow off the shelf. This characteristic can tend to increase the zone of influence of estuarine and coastal activities into shallow or deep shelf waters, potentially affecting the quality of HMS EFH. The heterogeneity of canyon environments results in communities that are generally richer biologically than those on the adjacent shelf and slope. Additionally, the species assemblages inhabiting the head, axis, and lower walls of large submarine canyons are frequently different from those found on the continental slope. Canyon assemblages are often dominated by large populations of sessile filter feeders, whereas slope assemblages usually consist of sparse mobile carnivore/scavenger populations.

On the north and mid-Atlantic continental slope and rise the epifauna is controlled by a combination of depth and topography (canyon vs. slope gradient). On the south Atlantic slope and rise, however, the epifauna appears to be controlled by a more complex oceanographic system dominated by a current regime which includes the Gulf Stream and Western Boundary Undercurrent, and by a greater diversity of substrate.

***South Atlantic Shelf*:** The south Atlantic continental shelf area can be divided into five types of habitat: coastal, open shelf, live-bottom, shelf-edge, and upper continental slope. Each of these types has its own distinctive characteristics and species assemblages.

The coastal habitat has a smooth sandy-mud bottom and is usually shallower than 20 m (66 feet). The open shelf habitat is found between depths of about 20 and 55 m (66 and 180 feet) and has a smooth, sandy substrate. This habitat predominates between the occasional live-bottom areas on the outer shelf. Typically, these are areas of relatively low productivity.

Live-bottom habitats, although sporadically distributed, are areas of high productivity and are usually found in water depths of approximately 20 to 55 m (66 to 180 feet). In shallower water, live-bottom areas are usually dynamic because water currents can transport the surface sand layer and cover existing communities or expose new hard bottoms for colonization. The deeper water live-bottom areas tend to be more stable. Thus, the complexity and average vertical relief of these live-bottom areas typically increase seaward. The exposed hard substrate in these areas has allowed colonization by many attached species, such as soft corals, and provides three dimensional habitat for many species, some of which are prey for HMS. These live-bottom areas provide habitat for the warm water snapper-grouper assemblage of fishes. In addition to these live-bottom communities, extensive banks of coral occur on the Blake Plateau at depths between 650 and 850 m (approximately 2,100 to 2,800 feet). Along the shelf-edge water depths average between 40 and 100 m (130 to 325 feet). The bottom topography varies from smooth mud to areas of high relief with associated corals and sponges. The lower-shelf habitat has smooth mud bottoms in water depths between 100 and 200 m (approximately 330 and 660 feet).

The shelf-edge habitat may range in water depth between 40 and 100 m (131 and 328 feet). The bottom topography varies from smooth sand to mud to areas of high relief with associated corals and sponges. The fish species found in this area include parrotfish (Scaridae) and the deepwater species of the snapper-grouper assemblage. Many juveniles of certain species of fish are found in *Sargassum* (pelagic brown algae) overlying this habitat, but the fate of these juveniles is unknown.

The final category in the south Atlantic, the upper continental slope habitat, has smooth mud bottoms in water depths of 100 to 200 m (328 to 656 feet). Many of the species in this zone are representatives of cold water northern species exhibiting tropical submergence (i.e., being located in deeper, cooler water as latitude decreases).

This pattern - hard and soft bottom habitats interspersed - also occurs in the south part of the Atlantic shelf (Miami to the Dry Tortugas). The Florida shelf is a limestone platform which is exposed in some areas and covered with quartz and carbonate sands in others. Off-shore hard bottom habitats usually consist of rock covered by a thin, mobile, sand veneer. These areas are usually colonized by a diverse biota of tropical and temperate species, including macroalgae, stony corals, soft corals, sponges, and bivalves. Overall, about 30 percent of the southwest Florida shelf consists of live bottom areas. In addition, this area contains most of the true coral reefs, and their associated fauna, found in North America. The coral reef areas are highly diverse habitats with complex three-dimensional space and relatively high biological productivity. In order to protect a diverse, fragile coral habitat off the coast of central Florida, the Oculina Bank has been designated a Habitat of Particular Concern (HAPC) by the South Atlantic Fishery Management Council. Within the HAPC, fishing with bottom longline, bottom trawl, dredge, pot, or trap, and also vessel anchoring, are prohibited, primarily to protect the delicately branching coral *Oculina varicosa* (SAFMC, 1998).

A topographic irregularity southeast of Charleston, SC, known as the Charleston Bump, is an area of productive sea floor which rises abruptly from 700 to 300 m (2,300 to 980 feet) within a distance of about 20 km, and at an angle which is approximately transverse to both the general isobath pattern and the Gulf Stream currents. The Charleston Gyre is a persistent oceanographic feature that forms in the lee of the Charleston Bump. It is a location in which larval swordfish have been commonly found and may serve as nursery habitat.

Deepwater banks occur predominantly beyond the outer edge of the continental shelf on the continental slope. Although their distribution is still being delineated, these structures have been identified in the west south Atlantic region, especially within Bahamian national waters, and have been reported in the Straits of Florida off Little Bahama Bank. Although most of them are outside U.S. waters, some do occur near the outer edge of the EEZ. The banks are composed of lithified sandy carbonate sediments supporting a regionally diverse array of benthic fauna, with ahermatypic branching corals forming most of the structure and habitats.

Physical Oceanography (Water Movements and Marine Habitats)
(Material in this section is largely a summary of information found in MMS, 1992; 1996. Original sources of information are referenced in those documents.)

The shelf area of the Mid-Atlantic Bight averages about 100 km (approximately 60 miles) in width, reaching a maximum of 150 km (approximately 90 miles) near Georges Bank and a minimum of 50 km (approximately 30 miles) offshore Cape Hatteras. The mean current flow is along-shelf and to the southwest, interspersed with localized areas where outflow from major estuaries (e.g., Connecticut River, Lower New York Bay, Delaware Bay, and Chesapeake Bay) interrupts the flow field. Current speeds are strongest at the narrowest part of the shelf where wind-driven current variability is highest. The slope area is influenced by the presence of the west Slope Sea Gyre, which is present 85 percent of the time with a relatively strong net southeastward flow along the New Jersey coast.

In the high northern latitudes, North Atlantic Deep Water (NADW) flows southward out of the Norwegian Sea and into the Labrador Sea, forming the Deep Western Boundary Current (DWBC) (also known as the Western Boundary Undercurrent). After taking a counter-clockwise course through the Labrador Sea, the DWBC flows around the Grand Banks of Newfoundland and then follows the topography of the U.S. Atlantic slope. It passes under the Gulf Stream near Cape Hatteras and continues into the South Atlantic. Meanders of the DWBC core account for variations in velocity and volume transport, according to measurements in the Blake Plateau region.

The continental shelf in the South Atlantic Bight varies in width from 50 km (32 miles) off Cape Canaveral, FL to a maximum of 120 km (75 mi) off Savannah, GA and a minimum of 30 km (19 miles) off Cape Hatteras. The shelf is divided into three cross-shelf zones. Waters on the inner shelf (0 to 20 m [0 to 66 feet]) interact extensively with rivers, coastal sounds, and estuaries. This interaction tends to form a band of low-salinity, stratified water near the coast that responds quickly to local wind-forcing and seasonal atmospheric changes. Mid-shelf (20 to 40 m [66 to 132 feet]) current flow is strongly influenced by local wind events with frequencies of two days to two weeks. In this region, vertically well mixed conditions in fall and winter contrast with vertically stratified conditions in the spring and summer. Gulf Stream frontal disturbances (e.g., meanders and cyclonic cold core rings) that occur on time scales of two days to two weeks dominate currents on the outer shelf (40 to 60 m [132 to 197 feet]).

The Gulf Stream produces periodic meanders, filaments, and warm and cold core rings that significantly affect the physical oceanography of the continental shelf and slope. This western boundary current has its origins in the tropical Atlantic Ocean (i.e., the Caribbean Sea). The Gulf Stream system is made up of the Yucatan Current that enters the Gulf of Mexico through the Yucatan Straits; the Loop Current which is the Yucatan Current after it separates from Campeche Bank and penetrates the Gulf of Mexico in a clockwise flowing loop; the Florida Current, as it travels through the Straits of Florida and along the continental slope into the South Atlantic Bight; and the Antilles Current as it follows the continental slope (Bahamian Bank) northeast to Cape Hatteras. From Cape Hatteras it leaves the slope environment and flows into the deeper waters of the Atlantic Ocean.

The flow of the Gulf Stream as it leaves the Straits of Florida is jet-like with maximum speeds at the surface that are usually about 200 cm/s. During strong events, maximum current speeds greater than 250 cm/s have been recorded offshore of Cape Hatteras. The width of the Gulf Stream at the ocean surface ranges from 80 to 100 km (50 to 63 miles) and extends to depths of between 800 and 1,200 m (2,624 to 3,937 feet).

Meandering events of the Gulf Stream are caused by atmospheric forcing or bathymetric features (e.g., the Charleston Bump). Meanders are lateral oscillations of the mean current stream (flow field) produced by migrating waves. They may affect the location of the Gulf Stream's western boundary and have amplitudes (east-west displacement) of up to 25 km (15.5 miles) off the coast of Florida and Georgia. However, north of the Charleston Bump, the amplitude may increase to about 100 km (63 miles). Meanders occur periodically in the 2- to 15-day range.

As a meander passes, the Gulf Stream boundary oscillates sequentially onshore (crest) and offshore (trough). A meander can cause the Gulf Stream to shift slightly shoreward or well offshore into deeper waters. The Gulf Stream behaves in two distinct meander modes (small and large), with the size of the meanders decreasing as they move northward along the coast. During the large meander mode the Gulf Stream front is seaward of the shelf break, with its meanders having large amplitudes. Additionally, frontal eddies and accompanying warm-water filaments are larger and closer to shore. During the small meander mode the Gulf Stream front is at the shelf break. Frontal eddies and warm-water filaments associated with small amplitude meanders are smaller and farther from shore. Since HMS tend to follow the edge of the Gulf Stream, their distance from shore can be greatly influenced by the patterns of meanders and eddies.

Meanders have definite circulation patterns and conditions superimposed on the statistical mean (average) condition. As a meander trough migrates in the direction of the Gulf Stream's flow, it upwells cool nutrient-rich water, which at times may move onto the shelf and may evolve into an eddy. These boundary features move south-southwest. As warm-water filaments, they transfer momentum, mass, heat, and nutrients to the waters of the shelf break.

Gulf Stream filaments are mesoscale events which occur regularly offshore the southeast United States. The filament is a tongue of water extending from the Gulf Stream pointing to the south. These form when meanders cause the extrusion of a warm surface filament of Gulf Stream water onto the outer shelf. The cul-de-sac formed by this extrusion contains a cold core that consists of a mix of outer-shelf water and nutrient-rich water. This water mix is a result of upwelling as the filament/meander passes along the slope. The period from genesis to decay typically is about two to three weeks.

The Charleston Gyre is a permanent oceanographic feature of the South Atlantic Bight, caused by the interaction of the Gulf Stream waters with the topographically irregular Charleston Bump. The gyre produces an upwelling of nutrients, which contributes significantly to primary and secondary productivity of the Bight, and is thus important to some ichthyoplankton, including swordfish larvae (Govoni *et al.*, in prep). The degree of upwelling varies with the seasonal position and velocity of the Gulf Stream currents.

In the warm waters between the west edge of the Florida Current/Gulf Stream and 20° N and 40° N, pelagic brown algae, *Sargassum natans* and *S. fluitans*, form a dynamic structural habitat. The greatest concentrations are found within the North Atlantic Central Gyre in the Sargasso Sea. Large quantities of *Sargassum* frequently occur on the continental shelf off the southeast United States. Depending on prevailing surface currents, this material may remain on the shelf for extended periods, be entrained into the Gulf Stream, or be cast ashore. During calm conditions *Sargassum* may form irregular mats or simply be scattered in small clumps. Oceanographic features such as internal waves and convergence zones along fronts aggregate the algae along with other flotsam into long linear or meandering rows collectively termed "windrows."

Pelagic *Sargassum* supports a diverse assemblage of marine organisms including fungi, micro- and macro-epiphytes, sea turtles, numerous marine birds, at least 145 species of invertebrates, and over 100 species of fishes. The fishes associated with pelagic *Sargassum* include juveniles as well as adults, including large pelagic adult fishes. Swordfish are among the fishes that can be found associated with *Sargassum*. The *Sargassum* community, consisting of the floating *Sargassum* (associated with other algae, sessile and free-moving invertebrates, and finfish) is important to some epipelagic predators such as wahoo and dolphin. The *Sargassum* community provides food and shelter from predation for juvenile and adult fish, and may have other functions such as habitat for fish eggs and larvae.

Offshore water quality in the Atlantic is controlled by oceanic circulation, which, in the mid-Atlantic is dominated by the Gulf Stream and by oceanic gyres. A shoreward, tidal and wind-driven circulation dominates as the primary means of pollutant transport between estuaries and the nearshore. Water quality in nearshore water masses adjacent to estuarine plumes and in water masses within estuaries is also influenced by density-driven circulation. Suspended sediment concentration can also be used as an indication of water quality. For the Atlantic coastal areas, suspended sediment concentration varies with respect to depth and distance from shore, the variability being greatest in the mid-Atlantic and south Atlantic.

Resuspended bottom sediment is the principal source of suspended sediments in offshore waters.

Coastal and Estuarine Habitats
(Material in this section is largely a summary of information found in MMS, 1992; 1996; NOAA, 1991; 1996; 1997a; and 1997b. Original sources of information are referenced in those documents.)

Although HMS move primarily through open ocean waters, they do periodically utilize inshore habitats. This is especially true for several species of sharks that move inshore, often into shallow coastal waters and estuaries, to give birth; these areas then become nursery areas as the young develop. Coastal habitats that may be encountered by HMS are described in this section. Those areas that are known nursery or spawning grounds, or areas of HMS aggregation for feeding or other reasons, are considered to be EFH for those species. It should be noted that characteristics of coastal and offshore habitats may be affected by activities and conditions occurring outside of those areas (farther up-current) due to water flow or current patterns that may transport materials that could cause negative impacts.

***Coastal Environments*:** A great diversity of shoreline types is found along the Atlantic coast. Pocket beaches (small sheltered areas between rocky headlands) are the dominant shoreline type in Massachusetts, Rhode Island, Connecticut, and along Long Island Sound. Much of the ocean frontage along Cape Cod and from Long Island to south Florida consists of sandy beach-dune and/or barrier beach areas. At the south tip of Florida and along the Florida Keys, swamps and mangroves are the dominant shoreline features. Mudflats exist along the shores of many of the bays and sounds, the most extensive found along the shores of Delaware and Chesapeake Bays and along the coast of Georgia. In addition, there are localized sections of dense shoreline development.

Beaches are particularly important for providing protection from storms, high tides, and wave action for the lagoons, sounds, wetlands, and low ground located landward of them. Natural dune areas found landward of sandy beaches often support seabirds, shorebirds, waterfowl, and a dune grass or shrub community. The ecologically fragile dune grass or shrub communities are important for maintaining beach and dune stability and are particularly intolerant of pollution or beach development. Mudflats, swamps, and mangroves occur in areas of low wave energy. These areas tend to act as sediment sinks, trapping nutrients that support a variety of plants, fish, birds, and mammals; they also trap and sequester pollutants.

The coastline of the mid-Atlantic is typified by elongated spit-barrier island complexes which separate the Atlantic Ocean from shallow, and usually narrow, lagoonal bays. The exceptions to this rule are the mouths of large drowned-river valley type estuaries (e.g., Chesapeake Bay, Delaware Bay and the Hudson-Raritan Estuary) and the unique back barrier lagoons of the Albermarle-Pamlico Sound system. Where large river valley estuarine embayments are absent, the mainland is generally protected from the wave-dominated coastal ocean by coastal barriers, which are commonly wide enough to support extensive development and thriving seasonal resorts. The Eastern Shore of Virginia is the lone exception. In this area, a nearshore meso-tidal hydrodynamic regime keeps the barrier islands from elongating, effectively disconnecting them from the mainland and isolating them from development pressures.

The coastal ocean is a shallow, nutrient-rich, and productive environment. Longshore currents transport sediments and nutrients parallel to the typically north-south running shoreline and are a primary cause of the elongate barrier islands and narrow inlets common in this region. The numerous inlets and other passageways for exchange between the estuarine and oceanic waters provide an important conduit between systems for a diverse suite of living marine resources, many of which spend significant portions of their lives in either medium, or require a specific habitat type for growth and development during a specific life stage. The opportunity for movement between two very different systems contributes greatly to the biological productivity and, thus, the commercial importance of the mid-Atlantic coast.

Sediments in the coastal zone are often coarse-grained compared with estuarine and outer continental shelf sediments. Wave action nearshore tends to segregate size fractions within the coastal zone such that a seaward fining of particles occurs from the beach face to the offshore areas. Deviation from this pattern often occurs at the mouths of major river valley estuaries where the outflow plume often deposits fine grained silts and clays in the nearshore zone. Typical sediments are a mixture of quartz particles and those of biogenic origin (i.e., shell fragments) with finer grains are encountered offshore.

The coastal zone is generally a high energy environment. As offshore swells and waves "feel" the bottom, they crest and break at the beach face. Storm energy is often concentrated in this zone as waves generated far offshore finally release their large amounts of latent power. This energy is often converted to strong currents which can carry large sediment loads and can erode shorelines and destroy man-made structures rapidly. Without hard structure for attachment, as is common in the mid-Atlantic, many sessile organisms cannot live in this environment. However, a number of attached animals find suitable substrate on man-made objects such as pilings and revetments, and many benthic filter-feeding organisms thrive in the rapid transfer of nutrients.

***Estuaries and Coastal Wetlands*:** The Gulf of Maine, a deep cold water basin, is nearly sealed off from the open Atlantic by Georges and Browns Banks, which fall off sharply into the continental shelf. Vineyard and Nantucket Sounds and Cape Cod are other major features of this region. The mid-Atlantic area is fairly uniform physically and is influenced by many large coastal rivers and estuarine areas, including Chesapeake Bay, the Nation's largest estuary, Narragansett Bay, Long Island Sound, the Hudson River, Delaware Bay, and the nearly continuous band of estuaries behind the barrier beaches from south Long Island to Virginia. The southern edge of the region includes the estuarine complex of Currituck, Albemarle, and Pamlico Sounds, a 2,500-square mile system of large interconnecting sounds behind the Outer Banks of North Carolina.

The south Atlantic is characterized by three long crescent shaped embayments, roughly separated by four prominent points of land: Cape Hatteras, Cape Lookout, and Cape Fear in

North Carolina; and Cape Romain in South Carolina. Low barrier islands occur along the coast south of Cape Hatteras, with concomitant sounds that are only a mile or two wide. These barriers become a series of large, irregularly shaped islands along the coast of Georgia and South Carolina, separated from the mainland by one of the largest coastal salt-marsh areas in the world. Similarly, a series of islands borders the Atlantic coast of Florida. These barriers are separated in the north by broad estuaries and in the south by narrow, shallow lagoons.

Estuaries are highly productive, yet fragile, environments that support a great diversity of fish and wildlife species. Many commercially valuable fish and shellfish stocks are dependent on these areas during some stage of their development. In the vicinity of North Carolina, Virginia, and Maryland, approximately 90 percent of the commercially valuable fish species are dependent on the estuaries for at least some part of their life cycle. Waterfowl, shorebirds, wading birds, and raptors use coastal wetlands for breeding, feeding, migrating, and wintering. A variety of reptilian, amphibian, and mammalian species are also common residents of coastal wetlands.

Estuaries contain a number of important habitats which thrive in the mixture of salt and fresh water, and provide a number of functions for aquatic and terrestrial organisms. Coastal wetlands such as salt marshes, tidal freshwater marshes and forested and non-forested non-tidal wetlands are common in mid-Atlantic estuaries. Submerged aquatic vegetation is a diverse group of rooted vascular plants that range from saline (true seagrasses) to fresh water. Their distributions are indicative of water quality, as they require a delicate balance of sediments, nutrients, and light to survive. Tidal flats, which are exposed to the air during low tides, are nondescript habitats that often are important in nutrient cycling and to seabirds as forage grounds.

Paralleling the Atlantic and Gulf of Mexico coastlines, the Intracoastal Waterway, an inland navigation channel, extends from Maine to Texas, connecting the Atlantic and Gulf estuaries and other coastal habitats which it intersects. Many of the species associated with those environments, including several species of coastal sharks, can be found within certain segments of the channel. In some areas of the Intracoastal Waterway deep pockets of water that are the result of dredging for navigational maintenance provide seasonal refuge in the winter from colder estuarine and coastal water temperatures.

Along the Atlantic seaboard coastal wetlands are located predominantly south of New York because these coastal areas have not been glaciated. Nearly 75 percent of the Atlantic coast salt marshes are found in the states of North Carolina, South Carolina, and Georgia. These three states contain approximately nine million acres of salt marsh.

Wetland vegetation provides stability to coastal habitats by preventing the erosion of sediments and by absorbing the energy of storms. The dominant salt marsh vegetation along much of the Atlantic coast includes the cordgrasses (*Spartina* sp.), salt grass (*Distichlis spicata*), needle rushes (*Juncus roemerianus*), and other salt tolerant species. Because of the unique adaptations necessary for plants to survive in salt water environments, species diversity is much lower than in freshwater environments.

There is a total of 13,900 square miles of estuarine habitat along the Atlantic coast. Approximately 68 percent (9,400 square miles) of this habitat occurs north of the Virginia/ North Carolina border, with Chesapeake Bay contributing significantly to the total. The dominant submerged aquatic vegetation in these estuaries are eelgrass (*Zostera marina*) and widgeongrass (*Ruppia maritima*). South of the Gulf of Maine, where there is a wider coastal plain and greater agriculture activity, estuaries carry higher sediment and nutrient loads. The increased fertility and generally higher water temperatures resulting from these nutrient loads allow these estuaries to support greater numbers of fish and other aquatic organisms.

South of the Virginia/North Carolina border, there are approximately 4,500 square miles of estuarine habitat. The Currituck, Albemarle, and Pamlico Sounds, which together constitute the largest estuarine system along the entire Atlantic coast, make up a large portion of these southern estuaries. A unique feature of these sounds is that they are partially enclosed and protected by a chain of fringing islands, the Outer Banks, located 32 to 48 km from the mainland. Dominant submerged aquatic vegetation in most of the southern estuaries are eelgrass, widgeongrass, and shoalgrass (*Halodule wrightii*).

Estuaries are more susceptible to pollution from land than other coastal water bodies. This susceptibility of an estuary to water quality problems varies depending on the extent of tidal flushing. An indication of the potential efficiency of tidal flushing is tidal range. With the exception of estuaries along the coasts of North Carolina and south Florida, most estuaries along the Atlantic coast are mesotidal, having tidal ranges from two to four meters. Estuaries along the coasts of North Carolina and south Florida are classified as microtidal, having tidal ranges less than two meters. Since microtidal estuaries exhibit poor tidal flushing capacity, North Carolina and south Florida estuaries are more susceptible to water pollution than are other estuaries along the Atlantic coast.

In Maryland and Virginia, the primary problems reported are excessive nutrients (nitrates and phosphates), particularly in the Chesapeake Bay and adjoining estuarine areas. Other problems included elevated bacterial and suspended sediment levels. Non-point sources were described as the main causes of pollution. Elevated bacterial levels were also listed as a local coastal pollution problem in Maryland.

In North Carolina, the primary problems listed for estuarine areas were enrichment in organics and nutrients, fecal coliform bacteria, and low dissolved oxygen. Insufficient sewage treatment and agricultural runoff are indicated as major causes of these pollution problems. Oil spills from vessel collisions and groundings, as well as illegal dumping of waste oil, are a common cause of local, short-term water quality problems, especially in estuaries along the north and mid-Atlantic coasts.

North Atlantic Estuaries: The high energy coast of the north Atlantic region is characterized by a rocky shoreline with numerous islands and small embayments. The region can be divided into two physiographic subregions, the Northern Gulf of Maine and the Southern Gulf of Maine. As HMS (e.g., bluefin tuna) are seasonally common in inshore areas within the Southern Gulf of Maine region, the estuaries that occur there are described in this section. (The sources of these descriptions are NOAA, 1991 and NOAA,1997a.)

Southern Gulf of Maine Estuaries: In the Southern Gulf of Maine, the dominant coastal features include Cape Cod, Massachusetts Bay, and Cape Ann. The coastline consists mainly of high-energy sand, cobble or gravel beaches and rocky shores. Estuarine surface water in this region covers approximately 961 square miles, with freshwater inflow to the area dominated by discharge from the Merrimack River and several smaller river systems. Following are descriptions of the major estuaries occurring in the Southern Gulf of Maine region.

Great Bay: The Great Bay estuarine system consists of Great Bay, Little Bay, the Piscataqua River and several smaller streams and rivers. The upper section of the estuary is shallow, while the lower region can reach depths up to 80 feet; the average depth for the estuary is 11.4 feet. Great Bay is generally a well mixed estuary, although moderate stratification can occur during periods of high flow. The tidal range near Portsmouth is nine feet. Turbidity occurs periodically with tides, and episodically with winds at any time of the year. Chlorophyll *a* concentration, an indication of primary productivity, ranges from low to high. Nuisance algal blooms in the mixing and seawater zones occur mainly from July through September, and have been known to affect biological resources. However, nitrogen and phosphorus concentrations are considered to be moderate. Although there are no reported observations of anoxia (oxygen depletion), hypoxia (extremely low oxygen conditions) has been reported in a small subarea of the mixing zone in July and August. Pelagic and benthic communities in Great Bay are considered to be diverse, with submerged aquatic vegetation coverage ranging from low to high densities, increasing in abundance in the mixing and seawater zones. In addition, the system includes approximately 2,700 acres of salt marsh.

Merrimack River: The Merrimack River, which is the major freshwater inflow to the region, is a shallow salt-wedge estuary (average depth of 11.8 feet) where salinities tend to be moderately to highly stratified throughout the year. The tidal range is 8.2 feet near the mouth of the estuary. Spatial coverage for submerged aquatic vegetation is considered to be medium in the mixing zone; however it has dramatically decreased in abundance since 1970. Approximately 2,300 acres of salt marsh are found within the estuary's drainage area.

Massachusetts Bay: Massachusetts Bay, a large coastal bay with smaller coastal embayments, has a circulation that is strongly influenced by tides and non-tidal surface currents. The average depth of the estuary is approximately 89.5 feet; the tidal range is approximately nine feet near Beverly Harbor. Salinities within the main bay are similar to those of the Gulf of Maine. Chlorophyll *a* concentrations are moderate, and nitrogen and phosphorus concentrations are considered to be within medium ranges throughout the year. However, nuisance and toxic algal blooms occur, the latter having an impact on biological resources. Occurrences of anoxia or hypoxia have not been noted. The planktonic and benthic communities are considered to be diverse, except in urban areas where the benthic community is dominated by annelids. Submerged aquatic vegetation has been on the decline, a situation that has been attributed to increased point sources and physical alterations to the watershed.

Boston Harbor: This estuarine system consists of Boston Harbor and several smaller coastal embayments. The average depth of the estuary is 25.8 feet. Within the main harbor, salinity is similar to that found in the Gulf of Maine, and is vertically homogeneous throughout the bay. Freshwater inflow is dominated by the Neponset River. Turbidity is considered to be medium, with highest levels occurring periodically between late spring and late summer. Circulation in the bay is strongly affected by tidal influences and non-tidal surface currents. The tidal range is approximately nine feet near the mouth of Boston Harbor. Chlorophyll *a* concentrations are moderate, with highs occurring periodically in summer. Nitrogen and phosphorus concentrations are considered to be moderate. Although nuisance and toxic algal blooms occur within the bay, they are not believed to be a problem to biological resources. While anoxic conditions have not been found, bottom hypoxia has been observed in the bay, in the Inner Harbor area, periodically from July through September, resulting in extensive biological stress within the area. Water column stratification is believed to be a contributing factor to the hypoxic conditions. The planktonic community in the bay is diverse; the benthic community is dominated by crustaceans in Boston Harbor and annelids in Boston Inner Harbor. Submerged aquatic vegetation has been on the decrease in the Boston Harbor seawater zone, this being attributed to epiphytes and disease.

Cape Cod Bay: Cape Cod Bay, the largest in the region, consists of a large coastal bay that is partially enclosed by Cape Cod, a ridge on the Coastal Plain consisting of glacial deposits, and four smaller bays and harbors. The average depth of the estuary is 77.1 feet. Circulation in the bay is strongly influenced by tides and non-tidal surface currents; tidal range is approximately nine feet near Wellfleet harbor. Turbidity concentrations are considered to be low, while chlorophyll *a* concentrations range from medium to high. While nitrogen concentrations range from medium to high, due to point sources, phosphorus is considered to be moderate. In the spring, nuisance algal blooms occur that do not appear to impact biological resources. However, toxic blooms that occur episodically in June do have an effect on biological resources. Although there are no observations of anoxia, hypoxia occurs in bottom waters periodically from July through September, causing biological stress conditions. Bottom dissolved oxygen in the embayments has decreased since 1970. Although the benthic community of the bay consists mainly of annelids near Plymouth, elsewhere it is diverse. There has been a decrease in submerged aquatic vegetation that is believed to be attributed to increases in non-point sources. Approximately 10,600 acres of salt marsh are known to occur within the Bay's drainage area.

Mid-Atlantic Estuaries**:** The estuarine systems in the Mid-Atlantic region from southern New England to the Virginia/North Carolina border include more than 7,790 square miles of surface water area. The shoreline along this region is irregular, with wide sandy beaches and extensive coastal and barrier island formations. The estuaries within this region can be divided into four major physiographic subregions: 1) Southern New England Coast, 2) New York Bight, 3) Delmarva Shore/Delaware Bay, and 4) the Chesapeake Bay. (The sources of the information presented in this section are NOAA, 1991; 1997b.)

Southern New England Coast Estuaries: This region extends from Cape Cod to Montauk Point, Long Island, and includes Long Island Sound. Within this area there are five major estuarine systems that encompass approximately 1,895 square miles of water surface area. The major coastal features include Buzzards Bay, Gardiners Bay and Long Island Sound, estuaries that are generally open to the Atlantic Ocean and subject to significant tidal mixing, resulting in high salinities. Freshwater inflow is dominated by groundwater, and, to a lesser extent, discharge from the Connecticut, Housatonic, and Blackstone rivers.

Buzzards Bay: Buzzards Bay is a glacial outwash dominated system consisting of the main bay and smaller coastal embayments, with the Elizabeth Islands breaching the main bay from Vinyard Sound to the south. Average depth of the estuary is 33.8 feet, and the tidal range is approximately four feet throughout the bay. Freshwater inflow from surficial sources is minimal, with groundwater seepage the major source of freshwater input to the bay. Salinity structure in the main bay is vertically homogeneous, and is essentially the same as seawater for the majority of the year. Chlorophyll *a* concentrations are generally moderate to high, showing maximum concentrations periodically in late spring to summer in the seawater zone. Nitrogen and phosphorus concentrations are considered to be moderate, although nitrogen is believed to have increased since 1970. Nuisance and toxic algal blooms do not appear to threaten biological resources. Maximum turbidity throughout the year occurs in the embayment subareas. Although anoxia has not been observed, episodic occurrences of hypoxia in the seawater embayments have been observed in bottom waters during the summer. The planktonic community is considered to be diverse, and the embayment benthic community is dominated by mollusks. Submerged aquatic vegetation has decreased due to changes in point sources. Salt marshes within the drainage area total about 4,100 acres.

Narragansett Bay: This estuarine system consists of Narragansett Bay and several smaller embayments. The average depth of the estuary is 30.2 feet. The tidal range is three feet at the mouth of the bay, increasing to approximately five feet near Warwick, RI. Bay circulation is affected largely by tidal mixing and wind currents, and the major freshwater inflow is from the Blackstone and Taunton rivers. Salinity structure in the bay is fairly homogeneous. Chlorophyll *a* concentrations are moderate to high, with maximum concentrations occurring in late spring to summer, light being the limiting factor in the tidal fresh and mixing zones, and nitrogen in the seawater zone. Nitrogen and phosphorus concentrations are high in the tidal fresh zone, and moderate to high in the mixing and seawater zones, with elevated nutrient conditions occurring from November to January. Nuisance algal blooms occur in all salinity zones periodically during the summer and have an impact on biological resources. Except in the seawater zone, where anoxia is not observed, periodic anoxia and hypoxia occur in bottom waters throughout the estuary from June to September, with water column stratification playing a moderate role in the development of these conditions. However, due to changes in point discharges, duration, frequency, and spatial coverages all have been on the decline. The planktonic community in the tidal fresh and seawater zones is dominated by diatoms, while in the mixing zone it is dominated by flagellates. The benthic community is a diverse mixture of organisms in the tidal fresh zone, and is dominated by annelids in the mixing and seawater zones. Submerged aquatic vegetation disappeared in the tidal fresh and mixing zones between 1938 and 1951. Salt marsh within the estuary covers approximately 3,800 acres.

Gardiners Bay: This system consists of Gardiners Bay and several smaller embayments. The average depth of the estuary is 20.2 feet; the tidal range is two feet near the entrance to Block Island Sound. Freshwater input is supplied primarily by groundwater sources, with minimal inflow contributed by the Peconic River. The salinity structure is essentially vertically homogenous with tidal mixing and wind being the significant forcing mechanisms. Both turbidity and chlorophyll *a* concentrations are high in the mixing zone and moderate to high in the seawater zone. Maximum chlorophyll *a* occurs episodically in the summer, with light being the limiting factor in the mixing zone and nitrogen in the seawater zone. Nitrogen and phosphorus concentrations are considered to be moderate. Episodic nuisance and toxic algal blooms occur in spring, summer and fall in both the mixing and seawater zones where they have impacted biological resources. There are no observations of anoxia or hypoxia. The planktonic community is considered to be diverse; submerged aquatic vegetation coverage has increased in recent years due to recovery from the effects of brown tides. The drainage area of the bay contains approximately 3,300 acres of salt marsh.

Long Island Sound: Long Island Sound is an expansive glacial outwash dominated estuarine system. The average depth of the estuary is 62.2 feet. The major freshwater input is from the Connecticut, Housatonic and Thames rivers. Turbidity is moderate to high. The tidal range is approximately 4.2 feet in the southern sound to nearly six feet in the northern sound. In the western sound, a stratified salinity structure is influenced by the East River, while in the eastern sound the salinities are higher and the variability less distinct. Chlorophyll *a* concentrations in the sound are high in the tidal fresh water and mixing zones, and there is a gradient of medium to hyper-eutrophic concentrations from the eastern to western seawater zone. Maximum Chlorophyll *a* occurs periodically in late spring/summer in the tidal fresh zone and in early spring/summer in the seawater zone. For the tidal fresh and mixing zones, the limiting factor is nitrogen, while in the seawater zone it is nitrogen, silica and light. Overall nitrogen and phosphorus are reported to be moderate to high. In all zones, nuisance algal blooms impact biological resources; toxic blooms affect resources in the seawater zone. Periodic bottom water hypoxia events occur from June to September in the mixing and seawater zones, and anoxia has been observed in the seawater zone. Duration, frequency, and spatial extent of these events have been on the increase due to changes in point and non-point sources, and an increased occurrence of stratification. The planktonic community is dominated primarily by diatoms and flagellates, and the benthic community by annelids. Decreases in submerged aquatic vegetation are attributed to point and non-point sources of pollution as well as disease. However, there are approximately 16,100 acres of salt marsh within the Sound's drainage basin.

Connecticut River: This estuary is a riverine subsystem to Long Island Sound, displaying a salt wedge salinity structure near the mouth. It is the major source of freshwater inflow to the middle and eastern sound, tending to cause lower spring salinities in that region due to the high freshwater discharge during spring runoff. Moderate stratification occurs during mean river stages. The average depth of the estuary is 12.5 feet, and the tidal range is approximately three feet near the mouth. Concentrations of chlorophyll *a* are high, with maximum levels occurring during the late summer; turbidity is considered to be moderate. Nitrogen concentrations are moderate, while phosphorus is low. Nuisance algal blooms occur in the tidal fresh zone during the summer and are reported to impact biological resources. Although episodic hypoxic events occur in the tidal fresh zone, the duration and spatial coverage of these events is declining due to reductions in point source pollution. Annelids dominate the benthic community in the mixing zone; salt marshes cover approximately 3,100 acres.

New York Bight Estuaries: The New York Bight subregion contains four major estuarine systems along the Long Island and New Jersey coastline, encompassing a total water surface area of 640 square miles. This region is dominated by wide sandy beach complexes and extensive barrier islands. Extensive salt marshes are also predominant throughout the area. Freshwater inflow sources include the Hudson River and smaller coastal-plain derived rivers, as well as groundwater.

Great South Bay: Great South Bay is a narrow, bar-built estuary containing a series of interconnected embayments and inlets where the freshwater inflow is dominated by groundwater sources and small coastal streams. The average depth of the estuary is 8.9 feet and the tidal range is approximately 2.5 feet near the inlets. Salinity structure is vertically homogeneous throughout the estuary. Chlorophyll *a* concentrations are moderate, while turbidity is considered to be high, with maximum levels occurring periodically in early summer. Nitrogen and phosphorus concentrations are moderate throughout the year, but nuisance algal blooms occur during the summer, and are reported to have an impact on biological resources. From July to September, periodic anoxic and hypoxic conditions occur throughout the water column in the mixing zone. Both the planktonic and benthic communities are diverse. Submerged aquatic vegetation coverage is low, having decreased due to brown tides. However, salt marshes within the drainage basin cover approximately 18,300 acres.

Hudson River/Raritan Bay: This estuarine system consists of a series of interconnected bays, rivers and tidal straits, with Raritan and Sandy Hook bays the two main bay systems. Responses of these areas to specific estuarine circulation forces are complex, and significant mixing occurs from the East River south to the lower bay area. Both saltwater intrusion and freshwater discharge from the Hudson River greatly reduce residence time within the estuary, where the average depth is 20.8 feet. The tidal range varies considerably throughout the system, but at the mouth of the East River is approximately 4.5 feet. Within the system, chlorophyll *a* concentrations range from moderate to hyper-eutrophic, particularly in Jamaica Bay, with maximum conditions occurring in the summer in all zones and also in the early spring in the mixing and seawater zones. Except for nitrogen in the lower bay, light is the limiting factor in all areas. Elevated nitrogen concentrations occur in March and from July to September in the mixing zone, while elevated phosphorus has been observed in the mixing zone in July and August and in the seawater zone in May, July, and August. Both nuisance diatom blooms, which are reported to affect biological resources, and highest turbidity occur in early spring and summer in the mixing and seawater zones. Anoxic events occur from June to August throughout the water column in Jamaica Bay, and hypoxic events from June to August in bottom waters of the seawater zone and throughout the water column in the mixing zone. Water column stratification is a significant factor in these developments. However, although increases in these events have been observed in the seawater zone due to point sources, decreases are occurring in the mixing zone. The planktonic community is dominated by diatoms in the tidal fresh zone, but is more diverse in the mixing and seawater zones. The benthic community is dominated by mollusks in the tidal fresh zone, annelids in the mixing zone, and annelids and crustaceans in the seawater zone. Submerged aquatic vegetation disappeared in the 1930s due to disease, and eutrophic conditions have prevented its re-establishment.

Barnegat Bay: Barnegat Bay is bar-built estuary containing a series of inter-connected embayments and inlets. The average depth of the estuary is 4.6 feet. Freshwater inflow is dominated by small coastal plain derived sources such as Toms River and Metedeconk River. Currents within the bay are driven mostly by winds, with significant circulation occurring near dredged channels. However, the salinity structure tends to be vertically homogeneous throughout the estuary. The mean tidal range is 3.1 feet near Barnegat Inlet, but within the main bay area is dampened considerably. Chlorophyll *a* within the bay is considered to be high, with maximums occurring periodically in late winter and late summer, nitrogen being the limiting factor. High turbidity events, which are wind driven, occur episodically during the summer. While phosphorus concentrations are generally low, nitrogen is reported to be moderate, with elevated concentrations evident from December to February. Biological resources are impacted by nuisance algal blooms that occur periodically during the summer. No occurrences of hypoxia or anoxia have been reported. Both the planktonic and benthic communities are considered to be diverse. Submerged aquatic vegetation coverage is moderate, and there are approximately 41,600 acres of salt marshes within the estuary drainage area.

New Jersey Inland Bays: This system consists of a narrow, bar-built estuary containing a series of interconnected embayments, small sounds and inlets. Freshwater inflow to the system is dominated by small coastal plain derived streams such as the Mullica and Harbor rivers. The salinity structure tends to be vertically homogeneous throughout the estuary, with significant circulation occurring near dredged channels. The average depth of the estuary is 6.2 feet and the tidal range is approximately 3.7 feet near the Little Egg Inlet and 4.1 feet near Wildwood, New Jersey. Chlorophyll *a* concentrations are high, maximums occurring in late summer with nitrogen the limiting factor. Observed trends are associated with changes in point and non-point sources and alterations to the basin. Turbidity concentrations are considered to be high, with the highest occurring periodically during the early summer. Nitrogen is moderate, while phosphorus is considered to be low. Nuisance algal blooms that are reported to affect biological resources occur episodically during the summer in the seawater zone. There are no reported events of hypoxia or anoxia. In the seawater zone, the benthic community is a diverse mixture of organisms, and the planktonic community is dominated by chlorophytes. Submerged aquatic vegetation coverage is unknown in the mixing zone and high in the seawater zone.

Delmarva Shore/Delmarva Bay Estuaries: The coastline of the Delmarva shore contains four major estuarine systems, having a total water surface area of approximately 990 square miles. It is dominated by a series of barrier islands, dune complexes, and wide, sandy beaches. Extensive salt marshes are also found throughout the area. Tides are a dominant influence on water column mixing, primarily near estuarine inlets, while wind plays a major role in the short-term salinity structure and circulation. With the exception of Delaware Bay, which is hydrographically distinct due to the dominance of the Delaware River, freshwater inflow is minimal, and a vertically homogeneous salinity pattern persists throughout much of the year.

Delaware Bay: Delaware Bay is a large riverine system with circulation dominated by discharge from the Delaware River. The bay is classified as a partially mixed or moderately stratified estuary. The average depth of the estuary is 20.8 feet. Tides range from approximately one foot near the mouth of the bay to approximately six feet near the Cohansey River. Salinity is highly variable due to flow changes from the Delaware River and freshwater runoff from coastal plain derived sources, with stratification more pronounced in the spring months. Turbidity levels are moderate to high. Chlorophyll *a* concentrations have been found to be high to hyper-eutrophic, and nitrogen and phosphorus concentrations are moderate to high, with elevated nitrogen occurring from December to February and elevated phosphorus from October to December, associated with point sources. Although the bay is an extremely nutrient-enriched system, it does not exhibit the classic symptoms of eutrophication that are observed in other estuaries. Nuisance algal blooms in the tidal fresh zone are reported to have an impact on biological resources. Low oxygen levels have historically been a problem in the estuary, and remain a concern. The planktonic community in the tidal fresh zone is considered to be diverse, while in the mixing and seawater zones it is dominated by diatoms. The benthic community is diverse in the tidal fresh and mixing zones, and is dominated by a combination of annelids and crustaceans in the seawater zone. A continuum of tidal marshes borders the shores of the Delaware estuary, ranging from salt marshes to brackish water marshes further up the estuary, to freshwater tidal marshes in the upper estuary. However, only about four percent of the tidal wetlands have been subject to permanent alteration. Salt marsh coverage within the drainage area is approximately 147,200 acres. There are no published accounts of recent occurrence of submerged aquatic vegetation. The relatively high natural turbidity in the estuary is presumed to prevent the establishment of these grasses.

Delaware Inland Bays: This is a shallow back-barrier lagoonal system comprised of Rehoboth and Indian River Bays. The average depth of the estuary is 4.2 feet. Although considered a partially mixed estuary, salinity stratification occurs, especially during the spring months. The tidal range may be as much as three feet near the Indian River Inlet; however, wind, shallow depths and tidal forcing combine to produce water column mixing such that the high nutrient and phytoplankton conditions do not usually produce anoxic or hypoxic conditions. Turbidity is considered to be high, with maximum levels occurring in January and in the summer. Elevated nitrogen and phosphorus concentrations occur from March to May for the former, while phosphorus concentrations are higher in July and August. Chlorophyll *a* concentrations are considered to be high, with maximums occurring periodically in the summer, phosphorus being the limiting factor in the mixing zone, and co-limiting with nitrogen in the seawater zone. Nuisance algal blooms occur in the summer, and have been reported to impact biological resources. While the planktonic community is diverse in the mixing zone, it is dominated by diatoms in the seawater zone. The benthic community is dominated by annelids in the mixing zone and crustaceans in the seawater zone. Submerged aquatic vegetation has not been noted in this system, although there are palustrine and estuarine emergent wetlands.

Maryland Inland Bays: This is a shallow lagoonal bay system that includes Ilse of Wight, Assawoman, and Little Assawoman Bays. Circulation is dominated by tidal influences, and, although considered a partially mixed estuary, salinity stratification occurs in the summer months, when freshwater input is minimal. The St. Martin River is the only significant freshwater inflow into system. Tidal range is approximately three feet near Ocean City, MD. Nitrogen concentrations are reported to be medium to high and phosphorus to be high, with elevated nutrients occurring from June to August, associated with point sources. The estuary has been noted to have hyper-eutrophic conditions - chlorophyll *a* concentrations range from high to hyper-eutrophic - a situation that seems to be improving. Turbidity is high in the summer, and episodically high throughout the rest of the year. However, low dissolved oxygen conditions have not been reported. In the seawater zone, nuisance algal blooms have been reported that have caused impacts on biological resources. The planktonic community is dominated by flagellates, and the benthic community dominated by mollusks in the mixing zone and crustaceans in the seawater zone. Submerged aquatic vegetation is not present in the mixing zone, but can be found in the more saline portions near the Assateague Inlet. Salt marshes are the dominant type of coastal wetland in this ecosystem.

Chincoteague Bay: This bay, which is bounded on the seaward side by Assateague Island, a thin barrier island, is a fairly shallow bar-built estuary containing a series of interconnected embayments, small sounds and inlets. Average depth is 5.9 feet. Within the bay, tidal influence is dampened quickly with distance from Chincoteague Inlet; therefore, winds often drive water level and circulation. Tidal range is approximately 3.6 feet near Chincoteague Inlet, and considerably less within Chincoteague Bay. Freshwater input is from several small streams that drain a very small area of the Delmarva Peninsula. Chlorophyll *a*, nitrogen, and phosphorus levels are all considered to be moderate, while turbidity in the bay is high, with maximum concentrations occurring periodically in the summer, associated with point sources. Submerged aquatic vegetation coverage is low, but on the increase. Salt marshes dominate the coastal wetland habitat, totaling 24,900 acres.

Chesapeake Bay: The Chesapeake Bay is the largest estuary in north America and acts as the catchment basin for parts of seven states. It can best be described as a combination of several estuaries, all of which are drowned river valleys. The Chesapeake Bay proper extends from its mouth at Cape Charles and Cape Henry, VA, to the head-of-tide of the Susquehanna River in Maryland, and includes the estuarine areas of the James, York, Rappahannock, Potomac, Patuxent, Chester and Choptank Rivers, as well as many other small rivers, and several large embayments. The bay is described as a very complex and diversified ecosystem. Seawater enters the bay mouth and underlies the less dense freshwater flowing out. The seawater becomes diluted as it travels up the bay, yet its influence affects all the living resources within the estuary. In the freshwater-dominated west side of the bay, salinities are generally lower and more stratified than for the east side. The Chesapeake is generally very shallow; however, several relict channels from ancestral rivers remain as deep trenches, 60 feet or more, down the mainstem of the bay and the axes of the larger rivers. The Chesapeake exhibits the largest annual range of temperatures of any estuary in the world; in the cold winters, upper portions of the bay may freeze, and in a typical summer, subtropical water temperatures may exist. Extensive (approximately 50,000 acres) and diverse (15 species) seagrasses and other submersed rooted vegetation colonize fertile shallows. These grasses have been declining overall, although there are localized instances of regrowth. Relicts of once plentiful oyster beds still remain within the bay; over-harvesting and disease have reduced a once-thriving fishery to essentially a historic remnant. On the shoreline, large and small fringing salt marshes provide habitats and conduits of nutrient exchange between the terrestrial and aquatic habitats. Approximately 27,790 acres of salt marsh line the shores of the Chesapeake Bay, providing numerous functions and values. The bay is also one of the most highly impacted estuaries in the world, and one of the best studied and modeled. However, it is difficult to generalize about a water body that extends for over 200 linear miles. Therefore, it is more instructive to divide the bay into discrete sections. (The descriptions that follow utilize the boundaries set forth by NOAA's Estuarine Eutrophication Survey (NOAA, 1997b)).

Chesapeake Bay Mainstem: The Susquehanna River provides the primary source of freshwater to the upper Chesapeake Bay. This large drowned river valley is quite deep in places and has exhibited hypoxia and anoxia in these areas. The main stem of the bay covers 2,700 square miles of water, with 2,275 billion cubic feet of water filling the generally shallow basin. While the tidal range can be large in places, significant wind events can drive circulation, especially towards the head of the bay. A two-layer density structure is apparent during all seasons of the year, with salinity variability more apparent near the head of the bay. The nutrient load from the estuarine drainage area (24,730 square miles) is significant, and hyper-eutrophic conditions can be locally important. In the tidal fresh zone, elevated concentrations of nutrients occur all year; in the mixing and seawater zones elevated nitrogen occurs in the spring and elevated phosphorus in the summer, these trends associated with point and non-point sources. Chlorophyll *a* concentrations range from moderate to hyper-eutrophic, with maximum levels in the tidal zone occurring in the winter and summer, and in the mixing and seawater zones in the spring, with additional highs in the mixing zone in the summer. Turbidity ranges from low to high, with maximum levels occurring during the spring in the tidal fresh and upper mixing zones, and throughout the year in the lower mixing zone. Low dissolved oxygen conditions occur periodically in bottom waters during the summer, with water column stratification a significant factor. The planktonic community is generally dominated by diatoms in the spring and flagellates in the summer. The benthic community is dominated by annelids. Submerged aquatic vegetation coverage ranges from low to medium, and since 1980 has increased in the mixing and seawater zones.

Chester River: The Chester River estuary is a small tributary that drains 520 square miles of mostly agricultural lands on Maryland's east shore. Non-point sources of nutrients from these lands contribute to high total nitrogen and moderate total phosphorous throughout the estuary. Wind conditions commonly drive the circulation in this semi-enclosed basin. Bottom waters seasonally become hypoxic under appropriate conditions. The lack of tidal mixing results in a stratified water column which facilitates anoxic conditions. Submerged aquatic vegetation can be found in low abundance in the mixed salinity areas.

Choptank River: The Choptank River, adjacent Trippe Bay, and several small creeks make up this segment of the Chesapeake Bay. Freshwater inflow from the upland is minimal, yet nutrient input from the lands within the drainage basin (1,339 square miles) is significant. Tidal mixing may be overcome by wind events. The nutrient load and low tidal flushing provide a good environment for eutrophication, and, accordingly, phytoplankton concentrations are high. Low dissolved oxygen conditions have been noted in bottom waters in the summer months. Submerged aquatic vegetation maintains comparatively low coverage, but may be on the increase.

Patuxent River: The Patuxent River estuarine drainage area encompasses 932 square miles of moderately developed upland. Both the tidal fresh and mixing portions have shown large chlorophyll *a* concentrations seasonally, and nutrient concentrations remain high although they have been gradually decreasing. Submerged aquatic vegetation typically has exhibited low coverage in both salinity zones, with regrowth noted in the tidal fresh water areas.

Potomac River: Several small rivers discharge into the estuarine portion of the Potomac River. In addition, the Potomac River itself drains parts of four states. The result is a large inflow of fresh water into the estuary (15,900 cfs from the estuarine drainage alone) and a large tidal fresh water zone (75 square miles). The drainage area is highly developed urban, residential and agricultural land, which results in significant non-point source run-off as well as point source pollution. The nutrient load is high for all reaches for nitrogen, and moderate for phosphorous. Eutrophic conditions may form in the summer, and anoxia and hypoxia may occur in deeper waters from May to September. Submerged aquatic vegetation has exhibited rapid regrowth from earlier declines in the upper mixing zone.

Tangier/Pocomoke Sounds: This subsystem incorporates the drainage for the Nanticoke, Wicomico, Manokin and Pocomoke Rivers and the shallow embayments their mouths form with the several low elevation islands that run down the axis of the lower Bay. This estuary drains around 3,200 square miles of land, and covers an actual area of 460 square miles. The drainage for this basin is significantly smaller than for those on the west side of the bay; that, coupled with tidal dynamics, maintains a higher salinity regime, on average. Nutrient inputs from the west half of the Delmarva Peninsula (which is highly utilized for agriculture) are significant, but dissolved oxygen conditions do not reach hypoxic levels, probably due to tidal flushing. This area supports significant submerged aquatic vegetation, which is decreasing in the mesohaline areas of this region.

Rappahannock River: A relatively undeveloped estuarine drainage area of 1,169 square miles feeds into the Rappahannock River estuary. This drowned river valley system has low freshwater inflow and a small tidal fresh water segment. Nutrient inputs have been classified as moderate, and chlorophyll *a* concentrations are high throughout the estuary in late spring and summer. The lower portions may become stratified in the summer, and anoxic and hypoxic conditions may form in the deeper areas. Submerged aquatic vegetation coverage is very low to low, although it has increased moderately in the mixing zone.

York River: The Mattaponi River and Pamunkey River converge to form the York River in a relatively underdeveloped estuarine drainage basin covering 2,654 square miles. The freshwater inflows from these rivers are significant and the tidal regime and basin hydrography are such that large portions of each are tidal fresh water systems with tide ranges nearing four feet. Stratification is common in this system, and hypoxia may form in the mixed salinity zone under such conditions. Some submerged aquatic vegetation beds may be found in the tidal fresh water and mixed salinity zones, and extensive emergent fresh water wetlands are located within each tributary.

James River: The James River provides much of the fresh water input into the lower Chesapeake Bay. Tidal freshwater portions of this major estuary reach up towards the fall line in Richmond, Virginia. This estuary drains a significant portion of southern Virginia (4,447 square miles), which contains a mixture of land-uses from heavy industrial, to agricultural, to forests and forested wetlands. Upper portions of the James may exhibit hyper-eutrophic conditions; all portions exhibit significant nutrient loadings and high chlorophyll *a* concentrations. Dissolved oxygen concentrations do not reach critical biological levels, probably due to the large tidal and freshwater inflow influences. Vertical stratification and bi-directional estuarine currents may develop in the summer months. Submerged aquatic vegetation can be found in the lower James River estuary, although turbidity is typically high in all seasons.

East Shore of Virginia Bays: Water quality information for this small stretch of mesotidal bays along the southeast tip of the Delmarva is not available; some studies indicate that adjacent land use (primarily agriculture) influences water quality. The barrier islands, which provide protection from the open ocean, are very dynamic, migrating with the longshore current, disintegrating and reforming as conditions change. This area is suitable for emergent wetlands, salt tolerant seagrasses and oyster beds, and is protected from development by virtue of its naturally dynamic nature.

***South Atlantic Estuaries*:** South Atlantic estuaries encompass more than 4,440 square miles of water surface area. The region is characterized by extensive coastal and barrier features, and can be divided into three distinct subregions: Carolina Capes, Sea Island Coast, and the Florida Coast. (The sources of the following information are NOAA, 1971; 1996.)

Carolina Capes Estuaries: The major coastal features in this region are the extensive shoal structures and the series of barrier islands off North Carolina and South Carolina. Extensive salt marshes also predominate throughout the area. Due to the proximity of the west edge of the Gulf Stream off the Outer Banks, salinities in this area tend to be higher than for other Atlantic estuaries. Otherwise, wind plays a major role in short-term salinity structure and circulation within the estuaries. Near the inlets, tides are a dominant influence on water column mixing.

Albemarle/Pamlico Sounds: The Albermarle and Pamlico Sound system is the largest back-barrier lagoon system in North America, and is second only to the Chesapeake Bay in surface area, covering 27,686 square miles. The average depth of the estuary is 13.5 feet. The tidal range is two feet near the inlets, but is dampened to 0.6 feet within Pamlico Sound. Freshwater inflow into the Albemarle/Pamlico Sounds is dominated by discharge from the Roanoke, Chowan, Neuse-Trent and Tar-Pamlico river systems. This estuary drains 12,781 square miles of land within its basin, and is essentially enclosed, with only three small inlets providing its connection with the coastal ocean to the east. Tidal mixing is significantly reduced with distance from these inlets, and water level and circulation are primarily wind driven. Chlorophyll *a* levels are moderate to hyper-eutrophic, and turbidity levels moderate to high. Nitrogen and phosphorus levels are considered to be moderate to high. Periodic occurrences of nuisance and toxic algae have been recorded seasonally within the estuary. Current trends in water quality are unknown for the most part, although anoxia and hypoxia are reported for limited bottom areas. The planktonic community is dominated by blue-green algae in the Chowan River, and diatoms in Pamlico Sound and the seawater zone. Polychaetes and molluscs dominate the benthic community in the mixing and seawater zones. Fringing wetlands are found along the undeveloped portions of the shoreline, and extensive brackish marshes extend upstream. An estimate 157,600 acres of salt marsh exist within the drainage basin. Submerged aquatic vegetation can be found within the saline and mixing portions of the estuaries; an unexplained decline in the coverage of submerged aquatic vegetation has been reported.

Pamlico and Pungo Rivers: The Pamlico and Pungo Rivers comprise 170.6 square miles of water surface area that drain into Pamlico Sound to the east. Tides range from two feet near the inlets of the Outer Banks to one foot at the mouth of the Pamlico and Pungo Rivers. The estuary has an average depth of 9.4 feet, holding 44.7 billion cubic feet of water. It can be significantly influenced by local wind conditions, which often drive circulation and override astronomical tidal forcing. Periodically high levels of chlorophyll *a* occur in winter and summer, while turbidity levels are considered to be moderate. Nitrogen and phosphorus concentrations are also considered to be moderate, although elevated levels are seen from January to March. Low dissolved oxygen levels have been noted in the deeper portions of the estuary, probably a result of moderate nutrient inputs providing exploitable resources for algal blooms, some of which can be toxic (e.g., *Pfisteria piscicida*). The planktonic community is dominated by flagellates, and the benthic community by annelids and crustaceans. Limited amounts of submerged aquatic vegetation are reported in the mixing salinity zone, coupled with low amounts of fringing emergent wetlands (approximately 80 acres of 1,000 acres total coastal wetlands) allows the planktonic communities to dominate primary production within the estuary.

Neuse River: The Neuse River is one of the many rivers that eventually drain into the Pamlico/Albermarle Sound back barrier lagoon system. The estuarine portion includes areas of the Trent River to the south. The average depth of the estuary is 11.5 feet; the drainage area is 2,221 square miles. Salinity stratification often occurs near the mouth of the Neuse River, but is more common upstream. Chlorophyll *a* concentrations are considered to be moderate to hyper-eutrophic. In the tidal fresh zone elevated nitrogen and phosphorus are known to occur from February to June, while in the mixing zone they are elevated from January to April and June to August, respectively. Although overall concentrations are considered to be moderate, their combination with a low flow and mixing have contributed to occasional seasonal hypoxic and anoxic conditions from June to October. Also, toxic or nuisance algal blooms have been reported to impact biological resources from early summer to early fall. The planktonic community is diverse; the benthic community is dominated by annelids. Submerged aquatic vegetation coverage is low, and has been identified as generally decreasing in areal coverage. In keeping with the land cover characteristics of coastal North Carolina, most of the wetlands are of the forested non-tidal variety known locally as pocosins.

Bogue Sound: The Bogue Sound system is a typical back-barrier lagoonal system, and is therefore very saline and shallow - the average depth of the estuary is 4.6 feet. A drainage area of 691 square miles feeds into the 12.9 billion cubic feet of the sound system, which receives freshwater inputs from the White Oak, Newport and North Rivers, all of which become vertically stratified in late winter and spring. Within the lagoonal system, however, tidal and wind driven mixing promote a vertically homogeneous salinity regime. The system is considered to have moderate levels of chlorophyll *a*, with maximums occurring in the spring in the mixing zone and in the summer in the seawater zone, nitrogen being the limiting factor in both. Nitrogen levels are moderate, while phosphorus concentrations are low. Toxic algal events are rare, although nuisance algal blooms occur on occasion. Diatoms are known to dominate the planktonic community; the benthic community is dominated by annelids. In addition, the Bougue estuarine system includes 21,100 acres of salt marshes. There are limited submerged aquatic vegetation resources within the sound and up into the more mixed salinity reaches.

New River: The New River estuary is classified as a drowned river valley estuary. Three large bays - Morgan, Farnell and Stones - comprise the upper reaches of the estuarine portion of the New River, which drains 470 square miles of land in its drainage basin. The estuary is relatively small (32.8 square miles in surface area, 5.2 billion cubic feet in volume) with a stable salinity structure and nearly vertical mixing in the tidally dominated reaches. The estuary averages 5.8 feet in depth and is deepest in the mixed salinity zones. Tidal influence is generally restricted to the lower estuary where increases in vertical mixing cause relatively stable salinities to persist. Moderate stratification is common in the upper portion of the New River, especially during high inflow conditions. Chlorophyll *a* concentrations are moderate to hyper-eutrophic, and moderate to high levels of turbidity have been found. Both reach maximum levels periodically in the mixing zone in the summer and winter, nitrogen and silica being the limiting factors. Nitrogen and phosphorus levels are moderate to high at differing times of the year, and both episodic nuisance and toxic algal blooms occur in summer and winter months, causing impacts to biological resources. Bottom water hypoxia occurs in the mixing zone from June to September, with water column stratification playing a role in these conditions. The planktonic community is dominated by a mixture of diatoms and flagellates; the benthic community in the seawater zone is dominated by annelids. Some submerged aquatic vegetation is present in very limited amounts in the seawater zone; however, 4,100 acres of salt marshes have been identified within the estuarine drainage basin.

Cape Fear River: The Cape Fear River estuary averages 11.5 feet in depth over a total surface area of approximately 38.3 square miles. It is a relative small estuary, holding 11.3 billion cubic feet of water, receiving freshwater input from the Cape Fear, Black and Northeast Cape Fear rivers. Although tides, which range to about four feet at the estuary mouth, are the dominant influence on the salinity structure of the estuary, seasonal variability in the riverine inputs also has major effects on the seasonal salinity structure. Nutrient levels within the estuary are reported to be high on average, compared with other estuaries. Chlorophyll *a* concentrations are moderate to high, with maximum concentrations occurring periodically from April to September, the limiting factors being light, phosphorus, and nitrogen, depending on location. High turbidity occurs in winter in all zones, especially with heavy rainfall and dredging activities. No hypoxia or anoxia have been observed. The planktonic community is dominated by a mixture of diatoms and flagellates; the benthic community is dominated by annelids. Very low amounts of submerged aquatic vegetation are present in all salinity zones. Also, 9,000 acres of salt marsh are estimated to occur within the Cape Fear drainage basin.

Winyah Bay: This estuary, with an average depth of 11.0 feet, receives the majority of its freshwater inflow from the Pee Dee and Little Pee Dee rivers. Seasonal variation in this inflow serves to alter salinities approximately ten parts per thousand (ppt) throughout most of the estuary. Moderately stratified conditions are most common within the mixing zone and navigation channels in the spring, shifting northward in the fall. The tidal range is 4.5 feet at North Inlet, where the vertical salinity structure is generally homogeneous. Chlorophyll *a* concentrations in the bay are moderate to high, maximums occurring periodically from late spring to fall. In the tidal fresh and mixing zones, phosphorus and light are generally the limiting factors for chlorophyll *a*, while in the North Inlet mixing zone and in the seawater zone nitrogen and light are limiting. Turbidity is high throughout the year. Nitrogen and phosphorus are reported to have moderate to high levels, positive trends generally associated with watershed management practices. Bottom water anoxia and hypoxia periodically occur in the mixing zone of Winyah Bay from May to September, and in the seawater zone of North Inlet in August and September. The planktonic community of the Winyah Bay system is dominated by diatoms, and the benthic community by insects in the tidal fresh zone and annelids in the mixing zone, while the seawater zones are diverse. Salt marsh coverage within the drainage basin is approximately 12,400 acres; the distribution and trends of submerged aquatic vegetation are generally unknown.

North and South Santee Rivers: This is a drowned river valley system with highly variable freshwater and salinity structures. Although horizontal salinity gradients exist, mainly in the lower estuary, stratification is generally weak. In the lower rivers salinities vary significantly between successive high and low tides, which range 4.2 feet near the estuary mouth. Nitrogen and phosphorus concentrations are reported to be moderate during the late summer months. No occurrences of nuisance algal blooms have been reported, and anoxia and hypoxia are unknown throughout the estuary. Trends for turbidity, nitrogen and phosphorus are reported as decreasing significantly due to rediversion of water in the estuary. Diatoms dominate the plankton community. Salt marsh covers approximately 12,900 acres within the drainage basin; current distribution and trends for submerged aquatic vegetation are unknown.

Sea Island Coast Estuaries: This coastal region consists of low-lying sea islands bordered by marshes, and relatively gently, periodically inundated, sloping marsh islands bound by tidal creeks. Deltaic structures within the Sea Island Coast resemble sediment filled drowned river valleys. Estuarine mixing here is primarily influenced by tidal fluxes, tidal ranges being higher in this region than in any other portion of the south Atlantic - as much as 7.2 feet near Savannah, Georgia. The major source of freshwater inflows in this region are from rivers originating in the coastal plain, the Appalachian Mountains and the Piedmont.

Charleston Harbor: Charleston Harbor is formed by the confluence of the Cooper, Ashley, and Wando rivers. The average depth of the estuary is 18.3 feet. Tides range approximately 5.2 feet near the harbor mouth, and have a dominant influence on salinity variability in the upper portions of the Ashley and Cooper rivers, the latter having more pronounced vertical stratification than other parts of the estuary. The harbor is characterized as having moderate to high levels of chlorophyll *a*, and high levels of turbidity, maximums for both occurring periodically in the summer in all zones. Biomass is limited by phosphorus and light in the tidal fresh and mixing zones, and by nitrogen and light in the seawater zone. Nitrogen and phosphorus are generally considered to be moderate, except for high concentrations in the Ashley River, and nuisance and toxic algal blooms are not known to have affected biological resources. Anoxia and hypoxia occur periodically during the late spring and summer in the mixing and seawater zones. The planktonic community is dominated by diatoms; the benthic community by insects in the tidal fresh zone, and a mixture of annelids and mollusks in the mixing and seawater zones. Salt marsh coverage within the drainage basin is approximately 26,800 acres; submerged aquatic vegetation, although on the increase, is reported as low in coverage.

St. Helena Sound: St. Helena Sound is a drowned river valley/bar-built system with numerous tributaries and island formations. Average depth of the estuary is 12.8 feet. The major freshwater source for the system is the South Edisto River. The dominant forcing mechanism affecting salinity structure is the semi-diurnal tides, which exhibit a range of 6.9 feet near the estuary mouth. Within the system, salinity structure varies, being weak and seasonally variable in the lower Combahee and South Edisto rivers, and vertically homogeneous in St. Helena Sound. The Sound is characterized as having low levels of chlorophyll *a* and high turbidity in the seawater zone. Nutrient levels are considered to be moderate, and ecological impacts from nuisance and toxic algal blooms are unknown. Periodic occurrences of anoxia in bottom waters and hypoxia throughout the water column are observed in the mixing zone from June to September. The planktonic community is dominated by diatoms and the benthic community by a mixture of annelids and crustaceans. Distribution and trends for submerged aquatic vegetation are unknown; there are approximately 91,600 acres of salt marsh within the drainage area.

Broad River: This is a drowned river valley system with intricate tidal creeks and marsh islands. The average depth of the estuary is 24.0 feet; tides range an average of 6.9 feet near the estuary mouth. The major freshwater inflow to the system is from the

Coosawhatchee River, with little seasonal variability. Chlorophyll *a* levels are considered to be moderate and turbidity low. Nitrogen and phosphorus are moderate to high, elevated nitrogen occurring in the mixing zone in February and again from August to October, while phosphorus is elevated in the mixing zone in July, August, and November, and in the seawater zone from June to August. Anoxia in bottom waters and hypoxia throughout the water column occur periodically in the mixing and seawater zones from June to September. The planktonic community is dominated by diatoms and the benthic community by a mixture of annelids and crustaceans. Distribution and trends for submerged aquatic vegetation are unknown; salt marshes within the drainage area cover approximately 88,300 acres.

Savannah River: The Savannah River is part of a drowned river valley system. The average depth of the estuary is 15.2 feet. The tidal range is 6.5 feet at the mouth, with tides the dominant forcing mechanism to the overall salinity structure, which is considered to be moderately stratified. Chlorophyll *a* levels within the river are considered to be moderate, maximum concentrations occurring periodically from June to August, with the limiting factors being light in the mixing zone and silica in the seawater zone. Ecological impacts from nuisance and toxic algal blooms are not reported. Turbidity levels are high throughout the year. Nitrogen and phosphorus are reported as moderate to relatively high, elevated concentrations occurring primarily from May to August in the tidal fresh and mixing zones. Anoxia occurs periodically from June to August, and hypoxia from May to September, both in bottom waters, and due to water column stratification. Fluctuations are associated with trends in non-point source pollution. The planktonic community in the Savannah River is diverse, while the benthic community is dominated by crustaceans in the tidal fresh zone and annelids in the mixing zone. The status of submerged aquatic vegetation in the tidal fresh zone is unknown, however, submerged aquatic vegetation is not present in the remainder of the estuary. There are approximately 32,200 acres of salt marsh within the drainage area.

Ossabaw Sound: This is a small coastal plain system that receives its freshwater inflow from the Ogeechee and Canoochee rivers. Seasonal variability in rainfall can alter salinity concentrations as much as ten parts per thousand in most of the estuary. Throughout the sound, which has an average depth of 14.3 feet, the tidal range is approximately 6.9 feet. The sound is characterized as having high to moderate levels of chlorophyll *a*, with maximum concentrations occurring episodically in the mixing zone and periodically in the seawater zone in April and May. Turbidity is considered to be moderate to high, while nitrogen and phosphorus are reported to be low to moderate, with maximum concentrations occurring from May to September. Anoxia and hypoxia do not occur. Submerged aquatic vegetation is not present in the estuary; salt marsh coverage totals 24,500 acres.

St. Catherines/Sapelo Sounds: This is a drowned river valley-barrier island system comprised of small tidal creeks. It receives minimal freshwater from mainland runoff, groundwater, and lateral flow from nearby rivers. The average depth of the estuary is 14.5 feet. Tides range from 6.5 to nine feet, and are the dominant forcing mechanism for salinity structure, which is generally homogeneous throughout most of the estuary. The system is characterized as having moderate levels of chlorophyll *a*, with maximum concentrations occurring periodically in the summer, light being the limiting factor in the mixing zone and silica in the seawater zone. Turbidity levels are high throughout the year. Nitrogen and phosphorus levels are generally low, although significant increases are known to occur in the mixing zone, associated with non-point sources. No anoxic or hypoxic conditions have been reported. The plankton community is diverse. Although submerged aquatic vegetation is not known to be present, salt marshes within the drainage basin total approximately 35,200 acres.

Altamaha River: This is a coastal plain system consisting of the Altamaha River and several tidal creeks. The average depth of the estuary is 10.2 feet. Seasonal freshwater inflow is the major forcing mechanism influencing salinity variability. Moderately to highly stratified conditions exist in the central and lower estuary; however, during high inflow vertically homogeneous conditions occur in the river above Onemile Cut. The semi-diurnal tide range averages 6.5 feet near the mouth of the estuary. Chlorophyll *a* levels are considered to be moderate to high, with maximum concentrations occurring episodically in the mixing zone, which represents approxi-mately 80 percent of the estuary, and periodically in the seawater zone in the summer, light being the limiting factor for the former and silica for the latter. Turbidity levels are reported to be high throughout the year. Nitrogen and phosphorus are low in the seawater zone and moderate elsewhere in the estuary; no anoxic or hypoxic conditions have been reported. Both the planktonic and benthic communities are dominated by a diverse mixture of organisms. Submerged aquatic vegetation is not present in the estuary; salt marshes cover approximately 7,900 acres.

St. Andrew/St. Simons Sounds: This is a drowned river valley system surrounded by barrier islands. The majority of the freshwater inflow is from the Satilla River. Salinity is weakly stratified, and, although it is dominated primarily by tidal mixing and the Satilla River, it is also influenced by the Altamaha River to the north. The tide ranges from 6.5 feet at the estuary mouth to 7.8 feet near Hermitage Point. The average depth of the system is 14.3 feet. Chlorophyll *a* for this system is considered to have moderate concentrations, with maximums occurring episodically in the mixing zone and periodically in the seawater zone in the summer, light being the limiting factor in the former and silica in the latter. No impacts on biological resources due to nuisance or toxic algal blooms have been reported, neither have anoxic nor hypoxic conditions. Nitrogen levels have been reported to be moderate to high, and phosphorus moderate, elevated levels of both occurring in the tidal fresh zone from March to May, and in the mixing zone from May to August. Both the planktonic and benthic communities are considered to be diverse. Submerged aquatic vegetation is not present; however, salt marsh coverage within the drainage basin is approximately 113,400 acres.

St. Marys River/Cumberland Sound: This is a bar-built estuarine system, receiving the majority of its freshwater inflow from the St. Marys River. The salinity structure is determined primarily by seasonal pulses from the river, with discharges the highest in the late winter and spring. The salinity structure is vertically homogeneous throughout most of the lower river and within Cumberland Sound due to tidal mixing. The average depth of the estuary is19.7 feet; tides average six feet near the mouth of the river. The system is characterized as having moderate chlorophyll *a* concentrations that reach maximums periodically from June to August, in the mixing zone the limiting factor being light, while in the seawater zone it is silica. No impacts on biological resources from nuisance or toxic algal blooms have been reported. Although nutrients are generally considered to be low, elevated concentrations occur from April to September in the seawater zone. No anoxic or hypoxic conditions have been reported. Both the planktonic and benthic communities are considered to be diverse. Submerged aquatic vegetation is not present.

Florida Coast Estuaries: The shallow lagoonal estuaries of Florida's Atlantic coast are semi-enclosed by extensive barrier island features. Horizontal density gradients can occur in these estuaries as a result of freshwater inflow from drainage canals on the west side, and tidal exchange through inlets on the east side.

St. Johns River: St. Johns River is an elongated estuarine system comprised of large lakes along most of the river's main stem. The average depth of the estuary is 12.0 feet. Tidal influences are most pronounced at the mouth of the river, where the tidal range is approximately four feet. The vertical salinity structure of the estuary is moderately stratified, this being influenced by tidal action, winds, and precipitation. The estuary is characterized as having high to moderate chlorophyll *a* levels, maximums occurring periodically from April to early fall, with light being the limiting factor in the tidal fresh and mixing zones, and residence time in the seawater zone. Turbidity is high to moderate, with highest levels occurring from April to July in the tidal fresh zone and from July to December in the mixing and seawater zones. Nutrient concentrations are relatively moderate except for high phosphorus levels in the seawater zone. There are periodic occurrences of nuisance algal blooms in June and July, and toxic dino-flagellates occur episodically. No anoxia or hypoxia has been observed. Diatoms dominate the planktonic community; the benthic community is dominated by annelids in the seawater zone and mollusks in the tidal fresh and mixing zones. There have been minor declines in submerged aquatic vegetation in the tidal fresh and mixing zones. However, there are approximately 16,800 acres of salt marsh within the estuarine drainage basin.

Indian River: This estuary is a narrow, lagoonal system that is influenced by winds, storm events, freshwater runoff, and evaporation. Although saltwater intrusion creates vertical stratification within the estuary and freshwater runoff influences lateral salinity, wind and storm events are the dominant forces affecting the overall salinity structure of the system. The average depth of the estuary is 6.6 feet; the tidal range is one foot near Ft. Pierce Inlet. High to hyper-eutrophic chlorophyll *a* levels and high turbidity are found in the estuary. Maximum levels of the former occur from spring to fall, with light the limiting factor in all zones, while highest turbidity is seen all year in the mixing zone, and at various times of the year elsewhere. Nuisance and toxic algal blooms occur periodically from June to August and result in impacts to biological resources. Elevated nutrient concentrations occur from April to September, as do anoxic and hypoxic conditions in bottom waters, this due to water column stratification. Flagellates are the dominant plankton, and the benthic community is dominated by annelids and crustaceans. Submerged aquatic vegetation is reported to be present in low to moderate amounts, and has been declining due to non-point sources of pollution. There are approximately 2,400 acres of salt marsh within the system.

Biscayne Bay: Biscayne Bay is a shallow lagoonal estuary that is influenced by flood control structures on canals and tributaries, and by upstream intrusion of saltwater, both of these factors affecting salinity patterns. The average depth is 7.7 feet. Circulation is tidally driven with wind also having an influence, this generally maintaining a vertically mixed water column throughout the estuary. The system is characterized as having generally low levels of chlorophyll *a*, with maximums occurring periodically in September and October, light being the limiting factor. Turbidity levels are considered to be low to moderate, reaching highest levels in the north mixing zone and seawater zones. Although nutrient concentrations are generally low to medium, elevated levels occur from September to January in the mixing and seawater zones. Anoxia and hypoxia, which are rare in the south mixing zone, occur in the north mixing zone from June to September, primarily in dredged areas and at the water surface in or near canals. High oxygen levels are found in the seawater zones, probably due to the unstratified nature of the water column. Diatoms dominate the planktonic community. The benthic community is dominated by submerged aquatic vegetation, which is widely distributed and on the slight increase in the north end of the seawater zone. Also, there are some hard-bottom areas that are dominated by soft corals and sponges. Salt marsh coverage within the drainage basin is approximately 10,400 acres.

5.4.2 Gulf of Mexico

The Gulf of Mexico supports a great diversity of fish resources that are related to variable ecological factors, such as salinity, primary productivity, bottom type, etc. These factors differ widely across the Gulf of Mexico and between inshore and offshore waters. Characteristic fish resources are not randomly distributed; high densities of fish resources are associated with particular habitat types (e.g., east Mississippi Delta area, Florida Big Bend seagrass beds, Florida Middle Grounds, mid-outer shelf, and the De Soto Canyon area). The highest values of surface primary production are found in the upwelling area north of the Yucatan Channel and in the De Soto Canyon region. In terms of general biological productivity, the western Gulf is considered to be more productive in the oceanic region than is the eastern Gulf. Productivity of areas where HMS are known to occur varies between the eastern and western Gulf, depending on the influence of the Loop Current.

Continental Shelf/Slope Features
(Material in this section is largely a summary of information in MMS, 1992; 1996. Original Sources of information are referenced in those documents.)

The Gulf of Mexico is a semi-enclosed, subtropical sea with a surface area of approximately 1.6 million square km. The main physiographic regions of the Gulf basin are the continental shelf (including the Campeche, Mexican, and U.S. shelves), continental slope and associated canyons, the Yucatan and Florida Straits, and the abyssal plains. The U.S. continental shelf is narrowest, at only 16 km (9.9 miles) wide, off the Mississippi River. Evidence suggests that the river outflow effectively splits the shelf into the Texas/Louisiana west province and the Mississippi/Alabama/Florida east province. The continental shelf width varies significantly from about 350 km (217 miles) offshore west Florida, 156 km (97 miles) off Galveston, TX, decreasing to 88 km (55 miles) off Port Isabel near the Mexican border. The depth of the central abyss ranges to 4,000 m (13,000 feet). The Gulf is unique because it has two entrances: the Yucatan Strait and the Straits of Florida. The Gulf's general circulation is dominated by the Loop Current and its associated eddies. The Loop current is caused by differences between the sill depths of the two straits. Coastal and shelf circulation, on the other hand is driven by several forcing mechanisms: wind stress, freshwater input, buoyancy and mass fluxes, and transfer of momentum and energy through the seaward boundary.

The physiographic provinces in the Gulf of Mexico - shelf, slope, rise, and abyssal plain - reflect the underlying geology. In the Gulf, the continental shelf extends seaward from the shoreline to about the 200-m water depth and is characterized by a gentle slope of less than one degree. The continental slope extends from the shelf edge to the continental rise, usually at about the 2,000-m (6,500 feet) water depth. The topography of the slope in the Gulf is uneven and is broken by canyons, troughs, and escarpments. The gradient on the slope is characteristically one to six degrees, but may exceed 20 degrees in some places, particularly along escarpments. The continental rise is the apron of sediment accumulated at the base of the slope. The incline is gentle with slopes of less than one degree. The abyssal plain is the basin floor at the base of the continental rise.

Texas/Louisiana Shelf Features**:** The shelf and shelf edge of the central and western Gulf are characterized by topographic features that are inhabited by hard-bottom benthic communities. The habitats created by the topographic features are important in several respects: they support hard-bottom communities of high biomass, high diversity, and high numbers of plant and animal species; they support, as shelter and/or food, large numbers of recreational and commercially important fishes; they are unique to the extent that they are small, isolated areas within vast areas of much lower diversity; they are relatively pristine areas (especially the East and West Flower Garden Banks); and they have an aesthetically attractive intrinsic value. Benthic organisms (primarily corals) that contribute to the relief of these features are mainly limited by temperature and light. Although corals will grow or survive under low light conditions, they will do best while submerged in clear, nutrient-poor waters. Light penetration in the Gulf is limited by several factors including depth and events of prolonged turbidity. Hard substrate favorable to colonization by coral communities in the north Gulf is found on outer shelf, high relief features.

Because mid-shelf banks experience less light penetration and colder temperatures, the biota differs significantly from outer shelf banks. Instead of the high diversity coral reef zone found at the Flower Gardens (outer shelf), the mid-shelf banks tend to be dominated by zones of minor relief building activity, e.g., Sonnier Bank, Stetson Bank, and Claypile Bank. Claypile Bank, with only ten meters of relief, is considered a low-relief bank and is often enveloped by the nepheloid layer. Thus, the level of biological community development is lowest at Claypile Bank. Two other mid-shelf banks, 32 Fathom Bank and Coffee Lump, have reliefs less than ten meters and are also considered to be low-relief banks. Geyer Bank, which crests at 37 m (within the depth that the high-diversity coral reef zone would be expected), does not contain a coral reef, and only minor reef building has occurred.

The south Texas banks are geologically distinct from the shelf edge banks. Several of the south Texas banks are low-relief banks, have few hard-substrate outcrops, exhibit a reduced biota, and have a thicker sediment cover than the other banks. Sebree Bank is a low-profile feature located in 36.5 m (120 feet) of water. The highest area of the bank is about 31 m (102 feet) deep. The bank appears to be composed of large boulders mostly veneered by fine sediments. The low relief of the bank and the fine sediments covering it indicate that Sebree Bank frequently exists in turbid conditions. The biota of the bank appears sparse due to these conditions. The bank attracts abundant nektonic species that utilize the overlying water column.

***Eastern Gulf Shelf Features*:** Although the Gulf off Florida does not contain any of the topographic features common to the offshore areas of Texas and Louisiana, the Florida offshore waters do contain several habitats of particular note which fall under the general definition of live bottom.

The “pinnacle trend” can be found in the waters south-southwest of Mobile Bay between 67 and 110 m (220 and 360 feet). The pinnacles appear to be carbonate reef structures in an intermediate stage between growth and fossilization. These features may have been built during lower stands of sea level and during the rise in sea level following the most recent ice age. The hard structure of the pinnacles provides a surprising amount of surface area for the growth of sessile invertebrates and attracts large numbers of fishes. The pinnacles are found at the outer edge of the Mississippi/Alabama shelf between the Mississippi River and the De Soto Canyon. The bases of the pinnacles rise from the sea floor between 50 and 100 m, with vertical relief of 20 m. These pinnacles may provide structural habitat for a variety of pelagic fishes and their prey.

The northwest Florida shelf is dominated by sand-bottom assemblages with low-relief, low-diversity communities widely interspersed with carbonate outcroppings. These outcroppings occasionally serve as attractors for hard-bottom biota and large aggregations of small fishes.

Live bottoms are regions of high productivity characterized by a firm substrate, supporting a high diversity of epibiota. These communities are scattered across the west Florida shelf in shallow waters with depth zonation apparent, and within restricted regions, off Louisiana, Mississippi, and Alabama. The density of the epibiotal communities varies from sparse to 100 percent coverage of the bottom, and largely depends on bottom type, current regimes, suspended sediments, habitat availability, and anthropogenic perturbations. Sessile epibiota include seagrasses, algae, sponges, anemones, encrusting bryozoans, and associated communities. For purposes of this document, live bottoms also include rocky formations with rough, broken, or smooth topography.

The Florida Middle Ground is probably the best known and most biologically developed of the east Gulf live bottoms, with extensive habitation by hermatypic (reef building) corals and related communities. This area is 160 km (99 miles) west-northwest of Tampa and has been designated as a Habitat Area of Particular Concern (HAPC) by the Gulf of Mexico Fishery Management Council (50 CFR 638). Bottom longlines, traps and pots, and bottom trawls are prohibited within the HAPC. The taking of any coral is prohibited except as authorized by permit from NMFS.

The Florida Middle Ground represents the northernmost extent of coral reefs and their associated assemblages in the east Gulf. The Middle Ground is similar to the Flower Garden Banks off Texas (typical Caribbean reef communities), although having a reduced number of species present, probably because it is nearer to the northern limit of viable existence for these types of coral communities. In the Caribbean, reefs may grow as deep as 80 m (260 feet), while in the Gulf they seem to be limited to a depth of about 40 m (130 feet). The Middle Ground reefs rise essentially from a depth of 35 m (115 feet), with the shallowest portions about 25 m (80 feet) deep. The Florida Middle Ground supports numerous Caribbean fishes, coral, and other invertebrate species. This is probably due to the intrusion of the Loop Current, short periods of low temperatures, and high biological productivity.

The southwest Florida shelf, with water depths between ten and 200 m (33 to 660 feet), has been characterized as having several biological assemblages that are associated with particular substrates and depths. Although depth is probably not the decisive factor in determining the distribution of the biotic assemblages, three major biotic depth zones are evident. There appears to be an innershelf zone between ten and 60 m (33 to 197 feet) water depths, a transitional zone between 60 and 90 m (197 to 297 feet), and an outer-shelf zone from 90 to 200 m (297 to 660 feet). A brief description of each assemblage can be found in the Gulf of Mexico Council's EFH amendment (GMFMC, 1998).

The Florida Keys comprise an important shallow water, tropical, coral reef ecosystem that is unique on the continental shelf of North America. The coral reefs of the Keys are vital to the economy of Florida. Commercial and recreational fishing, as well as non-consumptive uses such as boating, scuba diving, snorkeling, and educational and natural history activities, are economically important. The Florida reef tract is the only shallow water tropical coral reef ecosystem found on the continental shelf of North America. The Florida Keys archipelago, extending from Soldier Key to the Dry Tortugas, exhibits a diverse array of hard-grounds, patch reefs, and bank reefs from nearshore to 13 km (eight miles) offshore.

Patch reefs are the principal reef form between Elliott Key and Key Largo, where approximately 5,000 patch reefs are found. These reefs typically occur in water depths of about two to nine meters (6.6 to 30 feet). Bank reefs occur 7.4 to 13 km (4.6 to eight miles) seaward of the Keys, paralleling the coast, with most occuring off Key Largo and from Big Pine Key to Key West where major islands protect the reefs from the detrimental influence of Florida Bay waters. A reef flat is located on the inshore side of bank reefs. The deepest portions of the Florida bank reefs are in 37 to 40 m (121 to 132 feet) depths and occur as isolated outcrops surrounded by sediments. The Dry Tortugas are composed of islands, shoals, and reefs located about 117 km (73 miles) west of Key West.

Physical Oceanography (Water movements and Marine Habitats)
(Material in this section is largely a summary of information in MMS, 1992; 1996. Original sources of information are referenced in those documents.)

The Gulf receives large amounts of freshwater runoff from the Mississippi River as well as from a host of other drainage systems. This runoff mixes with the surface water of the Gulf, making the nearshore water chemistry quite different from that of the open ocean. Sea surface salinities along the north Gulf vary seasonally. During months of low freshwater input, salinities near the coastline range between 29 to 32 ppt. High freshwater input conditions during the spring and summer months result in strong horizontal gradients and inner shelf salinities less than 20 ppt. The mixed layer in the open Gulf, from the surface to a depth of approximately 100 to 150 m (330 to 495 feet), is characterized by salinities between 36.0 and 36.5 ppt.

Sharp discontinuities of temperature and/or salinity at the sea surface, such as the Loop Current front or fronts associated with eddies or river plumes, are dynamic features that may act to concentrate buoyant material such as detritus, plankton, or eggs and larvae. These materials are transported, not by the front's movements or motion across the front, but mainly by lateral movement along the front. In addition to open ocean fronts, a coastal front, which separates turbid, lower salinity water from the open-shelf regime, is probably a permanent feature of the north Gulf shelf. This front lies about 30 to 50 km offshore. In the Gulf these fronts are the most commonly utilized habitat of the pelagic HMS species.

The Loop Current is a highly variable current entering the Gulf through the Yucatan Straits and exiting through the Straits of Florida (as a component of the Gulf Stream) after tracing an arc that may intrude as far north as the Mississippi-Alabama shelf. This current has been detected down to about 1,000 m below the surface. Below that level there is evidence of a countercurrent. The "location" of the Loop Current is definable only in statistical terms, due to its great variability. Location probabilities during March, the month of greatest apparent intrusion, range from 100 percent in the core location at 25° N, down to small probabilities (ten percent) near mid-shelf. Analysis has indicated an average northern intrusion to 26.6° N, within a wide envelope.

When the Loop Current extends into or near shelf areas, instabilities, such as eddies, may develop that can push warm water onto the shelf or entrain cold water from the shelf. These eddies consist of warm water rotating in a clockwise fashion. Major Loop Current eddies have diameters on the order of 300 to 400 km (186 to 249 miles) and may extend to a depth of about 1,000 m. Once these eddies are free from the Loop Current, they travel into the western Gulf along various paths to a region between 25° N to 28° N and 93° W to 96° W. As eddies travel westward a decrease in size occurs due to mixing with resident waters and friction with the slope and shelf bottoms. The life of an individual eddy, until its eventual assimilation by regional circulation in the west Gulf, is about one year. Along the Louisiana/Texas slope, eddies are frequently observed to affect local current patterns, hydrographic properties, and possibly the biota of fixed oil and gas platforms or hard bottoms. Once an eddy is shed the Loop Current undergoes major dimensional adjustments and reorganization.

Small anticyclonic (clockwise) eddies are also generated by the Loop Current. They have diameters on the order of 100 km (62 miles), and the few data available indicate a shallow vertical extent (ca. 200 m or 660 feet). These smaller eddies have a tendency to move westward along the Louisiana/Texas slope. Also, cyclonic (counterclockwise) eddies associated with the larger-scale eddy process have been observed in the east Gulf and the Louisiana/Texas slope. Their origin and role in the overall circulation are presently not well understood. A major eddy seems to be resident in the southwest Gulf; however, recent evidence points toward a more complex and less homogeneous structure.

Shelf circulation is complicated because of the large number of forces and their variable seasonality. A northward current driven by prevailing winds and the semi-permanent anticyclonic eddy exists offshore south Texas. A strong east-northeasterly current along the remaining Texas and Louisiana slope has been explained partly by the effects of the semi-permanent anticyclonic eddy and a partner cyclonic eddy. West of Cameron, LA (93° W), current measurements clearly show a strong response of the coastal current to the winds, setting up a large-scale anticyclonic gyre. The inshore limb of this gyre is the westward or southwestward (downcoast) component that prevails along much of the coast, except in July and August. Because the coast is concave, the shoreward prevailing wind results in a convergence of coastal currents. A prevailing countercurrent toward the northeast along the shelf edge constitutes the outer limb of the gyre. The convergence at the southwest end of the gyre migrates seasonally with the direction of the prevailing wind, ranging from a point south of the Rio Grande in the fall to the Cameron area by July. The gyre is normally absent in July but reappears in August/ September when a downcoast wind component develops.

The Mississippi/Alabama shelf circulation pattern is not well understood at present, akthough there appears to be a divergent flow near the delta region. Offshore Panama City, FL, the prevailing flow is eastward, but reversals occur at the time of maximum westward wind components. Offshore Mobile, Alabama, currents are eastward on the average, and flow reversals coincide with eastward winds. Most current reversals occur during the summer or during Loop Current intrusion events. The inner shelf general circulation is a two-season event. During the winter the water column is homogeneous and surface circulation is mainly alongshore and westward, with the cross-shelf component weaker and directed onshore. During spring-summer conditions, the surface flow is mostly eastward. Under winds with easterly components, the water tends to flow shoreward and accumulate against the shoreline, creating a pressure gradient that drives bottom water alongshore in the direction of the winds. However, Loop Current intrusions, when present, will completely dominate the shelf circulation.

The west Florida shelf circulation is dominated by tides, winds, eddy-like perturbations, and the Loop Current. The flow consists of three regimes: the outer shelf, the mid-shelf, and the coastal boundary layer. Also, the Loop Current and eddy-like perturbations are stronger in this region. During Loop Current intrusion events, upwelling of colder, nutrient-rich waters has been observed. In waters less than 30 m (98 feet) the wind-driven flow is mostly alongshore and parallel to the isobaths. A weak mean flow is directed southward in the surface layer. In the coastal boundary layer longshore currents driven by winds, tides, and density gradients predominate over the cross-shelf component. Common flow ranges from moderate to strong, and the tidal components are moderate. Longshore currents, due to winter northerlies, tropical storms, and hurricanes, may range much higher, depending on local topography, fetch, and duration. Longshore currents, consisting of tidal, wind-driven, and density-gradient components, predominate over across-shelf components within a narrow band (ten to 20 km) close to the coast, referred to as the coastal boundary layer.

Sea-surface temperatures in the Gulf range from nearly constant throughout (isothermal) (29 to 30°C) in August to a sharp horizontal gradient in January, (25°C in the Loop Current core to 14 to 15° C along the northern shelves). Surface salinities along the northern Gulf are seasonal. During months of low freshwater input, salinities near the coastline range between 29 to 32 ppt. High freshwater inputs (spring-summer months) are characterized by strong horizontal salinity gradients and inner shelf values of less than 20 ppt. The vertical distribution of temperature reveals that in January, the thermocline depth is about 30 to 61 m (98 to 200 feet) in the northeast Gulf and 91 to 107 m (298 to 350 feet) in the northwest Gulf. In May, the thermocline depth is about 46 m (150 feet) throughout the entire Gulf.

Dissolved oxygen varies seasonally, with a slight lowering during the summer months. Very low oxygen levels (hypoxia) have been found in some areas of open Gulf bottom waters. A zone of hypoxia affecting up to 16,500 square kilometers of bottom waters during mid-summer on the inner continental shelf from the Mississippi River Delta to the upper Texas coast has been identified, most likely the result of high summer temperatures combined with freshwater runoff carrying large nutrient loads from the Mississippi River.

Coastal and Estuarine Habitats

(Material in this section is largely a summary of information in MMS, 1996; Field *et al.*, 1991; and NOAA 1997c. Original sources of information are referenced in those documents.)

***Beaches and Barrier Islands*:** Coastal barrier land forms in the Gulf of Mexico consist of islands, spits, and beaches that stretch in an irregular chain from Texas to Florida. These elongated, narrow land forms are composed of sand and other unconsolidated, predominantly coarse sediments that have been transported and deposited by waves, currents, storm surges, and winds.

The barrier islands of the Gulf of Mexico occur in five settings: the continuous barrier chain of the Texas coast, the barriers of the Chenier Plain along the northwest Texas and west Louisiana coasts, the Mississippi River Deltaic Plain barrier islands, the barrier islands of Mississippi Sound, and the barrier chain along the Florida coast.

A nearly continuous barrier shoreline extends along the Texas coast from south Texas to Rollover Pass, TX. The barrier islands and spits were formed from sediments supplied from three deltaic headlands: the Trinity delta in Jefferson County immediately west of the Sabine River; the Brazos Colorado Rivers delta complex in Brazoria and Matagorda Counties; and the Rio Grande delta in southernmost Cameron County.

The Texas barriers are arranged symmetrically around these erosional deltaic headlands. Erosional and accretionary barriers are about evenly split. Erosional barriers have developed along the deltaic headlands, and tend to be narrow, sparsely vegetated, and have a low profile and numerous washover channels. Accretionary barriers occur on either side of retreating deltaic headlands and tend to be wide, have prominent vegetated dunes, and contain few, if any, washover channels. Accretionary barriers grade into erosional barriers within interdeltaic embayments.

The Chenier Plain extends from west of the Texas barrier coast into the western part of coastal Louisiana. Here the coast is fronted by sandy beaches and coastal mudflats. The source of the mud is the sediment discharge of the Mississippi and Atchafalaya Rivers, which tends to drift westward along with the prevailing winds and associated nearshore currents. Fluid mud extends from the seaward edge of the marsh grasses to a few hundred yards offshore. The mud is an extremely effective wave-energy absorber. Consequently, the mainland shore is rarely exposed to effective wave action except during storms. The sand beaches that occur along the Chenier Plain rest against the mainland marshes. Although the beaches consist of only a thin accumulation of sand, and although some parts of the coast are experiencing erosion, some of the Louisiana Chenier beaches are advancing seaward. The Texas Chenier beaches are essentially erosive. Here, thin accumulations of sand, shell, and caliche nodules make up beaches that are migrating landward over tidal marshes. These beaches are narrow and have numerous overwash features and local, poorly developed sand dunes.

The Mississippi Sound barrier islands are relatively young, having formed some 3,000 to 4,000 years ago as a result of shoal bar aggradation; the positions of the islands have not changed significantly since that time. The islands are well vegetated by a southern maritime climax forest of pine and palmetto. The islands generally are stable with high beach ridges and prominent sand dunes. Although overwash channels do not commonly occur, the islands may be overwashed during strong storms. The islands show with no trend toward erosion or thinning, but trend toward westward migration in response to the predominantly westward-moving longshore currents. An exception to this general rule is Dauphin Island, Alabama, which is essentially a low-profile erosive barrier island, except for a small Pleistocene core at its east end. The Mississippi Sound islands are separated from each other by tidal inlets with deep, wide channels. These channels have associated ebb and flood tidal deltas. Shoals are adjacent to all the barriers. The barriers are separated from the mainland by the Mississippi Sound.

Along the panhandle coast of Florida to Cape San Blas the barrier islands and beaches fringing the coast are characteristically stable features with broad, high-profile beaches backed by dunes that are three to 4.5 m high. To the south and east of the Destin area the beaches tend to become narrower. Washover channels and fans occur locally and are generally the result of tropical storm impacts. Many of the beaches along the coast are backed by a series of beach ridges with each ridge truncating the previous one. These ridges indicate that in the past the coastline experienced alternating periods of erosion and deposition and changes in predominant littoral current directions.

The predominantly east-west trend of the barrier features along the panhandle coast terminates in the Cape San Blas area. Cape San Blas is the most prominent cuspate foreland in the Gulf of Mexico. Barrier islands and spits extend for as much as 50 km on either side of the Cape. The Cape and its associated islands have been accretionary or stable during the past several decades. Beyond Cape San Blas to just north of Tampa Bay the Florida coast takes on a concave-inward arcuate trend that is generally devoid of barrier features.

Barrier features appear again just north of Tampa Bay and continue to Cape Romano located just north of the Everglades National Park. The barriers along this stretch of the Florida coast occur in three successive barrier sequences consisting of eroding headlands, flanking spits, and adjacent barrier islands. The spit and island features are symmetrically distributed on either side of the eroding headland. Most of the barriers in southwest Florida are short, narrow, and of low topographic profile. In spite of this low profile, they do not have many washover features because of the low wave energy conditions that prevail here.

Although no true barrier land forms occur south of Cape Romano, the Florida Keys, consisting of linear, cemented limestone islands, provide habitats for unique local flora and fauna and for the quiet-water environment of Florida Bay. Functionally, therefore, they are acting as barriers.

Estuaries and Coastal Wetlands**:** There are 5.62 million hectares (ha) of estuarine habitat among the five states bordering the Gulf. This includes 3.2 million ha of open water, 2.43 million ha of emergent tidal vegetation (including about 162,000 ha of mangroves), and 324,000 ha of submerged vegetation. Estuaries are found from east Texas through Louisiana, Mississippi, Alabama, and northwest Florida. Estuaries of the Gulf of Mexico export considerable quantities of organic material, thereby enriching the adjacent continental shelf areas.

The importance of wetlands to the coastal environment has been well documented. Coastal wetlands are characterized by high organic productivity, high detritus production, and efficient nutrient recycling. Wetlands provide habitat for a great number and wide diversity of invertebrates, fishes, reptiles, birds, and mammals. Inshore and estuarine areas bordered by wetlands are particularly important as pupping and nursery grounds for juvenile stages of many important invertebrate and fish species including many species of Atlantic sharks.

Coastal wetland habitat types that occur along the Gulf Coast include mangroves, nonforested wetlands (fresh, brackish, and saline marshes), and forested wetlands. Marshes and mangroves form an interface between marine and terrestrial habitats, while forested wetlands occur inland from marsh areas. Wetland habitats may occupy narrow bands or vast expanses, and can consist of sharply delineated zones of different species, monospecific stands of a single species, or mixed plant species communities.

In Texas, coastal marshes occur along the inshore side of barrier islands and bays and on river deltas. Sparse bands of black mangroves are also found in this region. Broad expanses of emergent wetland vegetation do not commonly occur south of Baffin Bay at the north edge of Kennedy County because of the climate and hypersaline waters to the south.

Louisiana contains most of the Gulf coastal wetlands. These wetlands occur in two physiographic settings: the Mississippi River Deltaic Plain and the Chenier Plain. The present wetlands on the deltaic plain formed on top of a series of overlapping riverine deltas that have extended onto the continental shelf during the past 6,000 or so years. These wetlands are established on a substrate of alluvial and organic-rich sediment that is subject to high natural subsidence rates. The effects of subsidence are compounded by sea level rise. Under natural conditions, sedimentation encourages vertical accretion of wetland areas and may offset the submergence and inundation that result from subsidence and sea level rise. Areas of the deltaic plain that are located near an active channel of the Mississippi River tend to build outward and marsh areas tend to expand. At the same time, areas located near inactive, abandoned channels tend to deteriorate and erode as a result of the lack of sediment.

The Chenier Plain, located to the west of the Atchafalaya Bay in the western part of coastal Louisiana, is a series of separate ridges of shell and sand, oriented parallel or oblique to the coast, that are separated by progradational mudflats that are now marshes or open water. The mudflats are built during times when the Mississippi River channel is located on the west side of the deltaic plain or when minor changes in localized hydrologic and sedimentation patterns favor deposition in the Chenier area.

In Mississippi and Alabama, the mainland marshes behind Mississippi Sound occur as discontinuous wetlands associated with estuarine environments. The most extensive wetland areas in Mississippi occur east of the Pearl River delta near the west border of the state and in the Pascagoula River delta area near the east border of the state. The wetlands of Mississippi are more stable than those in Louisiana, reflecting the more stable substrate and more active sedimentation per unit of wetland area. Also, there have been only minor amounts of canal dredging in the Mississippi wetlands.

Most of the wetlands in Alabama occur on the Mobile River delta or along the northern Mississippi Sound. Between 1955 and 1979, fresh marshes and estuarine marshes declined by 69 percent and 29 percent, respectively, in these areas. On a percentage basis, wetlands loss has occurred more rapidly in Alabama during these years than it did in Louisiana. Major causes of non-fresh wetland losses were industrial development and navigation, residential and commercial development, natural succession, and erosion-subsidence. Loss of fresh marsh was mainly attributable to commercial and residential development and silviculture.

Coastal marsh habitat in Florida occurs for the most part north of Tampa Bay. To the south, because of milder winter temperatures, mangrove swamp predominates. In the northern part of the state, emergent wetlands have very little distribution in the Florida panhandle. The limited areas of wetlands that do occur occupy narrow, often discontinuous bands in saline and brackish zones behind barrier islands and spits, near river mouths, and along some embayments. The most extensive and continuous expanse of coastal marshland in the eastern Gulf occurs along the Big Bend coastline between Cape San Blas and Pasco County, just north of Tampa Bay. This stretch of the coast, which is important shark habitat, is exposed to very low wave energy because of the broad and very shallow offshore bank. This low energy environment allows the marsh edge to grow out directly into Gulf waters.

About 189,945 ha of mangroves are estimated to occur within Florida. About 90 percent of Florida's mangrove area occurs along the Gulf coast from the Caloosahatchee River to the southernmost part of the peninsula. Red, black, and white mangroves dominate the coastal swamps of Florida. The mangrove community may vary from a narrow fringe less than ten meters wide to extensive basin and riverine forests extending several kilometers inland. Extensive destruction of mangrove forests in Florida has occurred in various ways including outright destruction and land filling, diking, and pollution damage.

Along the 24,800-km Gulf coastline, 21 major estuaries are found on the U.S. coast. The amount of freshwater input to the Gulf basin from precipitation and a number of rivers - dominated by the Mississippi and Atchafalaya Rivers - is enough to influence the hydrography of most of the northern shelf. The basin's freshwater budget shows a net deficit, however, due to the high rate of evaporation.

***Gulf of Mexico Estuaries*:** Estuaries in the Gulf of Mexico encompass more than 23,938 square miles of water surface area. Historical periods of coastal flooding and intense sediment deposition have sculpted the Gulf shoreline into a gently sloping, lowland environment. The region can be divided in top four subregions: west Florida Coast, Big Bend/Panhandle Coast, Mississippi Delta/Louisiana Coast, and the Texas Coast. (The sources of information included in this section are Field *et al.*, 1991, NOAA 1997c, and GMFMC, 1998.)

Western Florida Coast Estuaries: The estuarine systems within the southern-most portion of this region are dominated by mangrove islands, tidal channels, and extensive wetlands found along the coastal fringe of the Everglades. The area is extremely complex and affected by tidal action, weather-related events and canal structures. From Cape Romano northward, the coastline consists of sandy beaches, some rocky areas, swamps, and tidal marshes. Freshwater inflow to the region is primarily from the

Hillsboro, Alafia, Peace, and Caloosahatchee river systems. Tidal range is approximately two to three feet throughout the region.

Florida Bay: Florida Bay is a shallow - average depth 7.3 feet - lagoonal estuary featuring innumerable mangrove islands, and mangrove forests fronting expansive marshes on the mainland. The systems are interconnected by extensive series of tidal creeks and natural passes. Approximately two thirds of the tidal marsh and more than 60 percent of the mangroves are in the area north of Cape Sable. A vertically mixed water column persists, and salinities are generally high to hypersaline, salinity variability being dominated by wind-driven circulation and weather events. The tidal range is approximately two feet near Cape Sable. Because most of this complex lies within the boundaries of the Everglades National Park, it has not been subjected to the extensive filling for housing and other purposes that estuarine areas farther to the north have experienced. The estuary is characterized as having low to high chlorophyll *a* concentrations and high turbidity. Nitrogen concentrations are medium to high, while phosphorus concentrations are low. Low dissolved oxygen contrations occur throughout the water column periodically between June and October. Nuisance and toxic algal blooms occur only in the seawater zone. The planktonic community varies throughout the bay, and is either dominated by blue-green algae and diatoms, or is a diverse mix of organisms; the benthic community is dominated by annelids in some areas, while in others it is considered to be diverse. Submerged aquatic vegetation coverage is moderate.

South and North Ten Thousand Islands: South Ten Thousand Islands is a shallow - average depth 6.5 feet - lagoonal estuary consisting of Whitewater Bay, and a number of features similar to the North Ten Thousand Islands system - small tidal rivers, small mangrove islands and tidal marshes. The average depth of the latter estuary is 5.7 feet. The majority of freshwater inflow to these systems is from overland sheet flow and regulated canal structures connected to Lake Okeechobee. Circulation in these systems is wind driven, and a vertically mixed water column exists. The tidal range is approximately 3.5 to 3.6 feet. Chlorphyll *a* concentrations are considered to be medium, with phosphorus and nitrogen the limiting factors, and turbidity levels high. Nutrient levels vary from low to high. Both hypoxia and anoxia occur from July to September, causing impacts on biological resources. Nuisance and toxic algal blooms have not been observed. The planktonic community in both systems is dominated by diatoms; the benthic community is considered to be diverse. Submerged aquatic vegetation coverage ranges from low to meduim; total salt marsh coverage for both systems is approximately 54,800 acres.

Charlotte Harbor/Caloosahatchee River: This system consists of Charlotte Harbor proper, Pine Island Sound, San Carlos Bay, Matlacha Pass, and the tidal areas of the Peace, Myakka, and Caloosahatchee rivers. The Caloosahatchee estuary is fed primarily by the artificially controlled flow of the Caloosahatchee River that traverses some 101 km (63 miles) from Lake Okeechobee. To the north is Charlotte Harbor (including Pine Island Sound), fed also by the Peace and Myakka Rivers. Charlotte Harbor is fronted by many islands and has more than 322 km (200 miles) of shoreline consisting primarily of mangrove forests and salt marshes. The average depth of the estuarine system is 8.7 feet; the tidal range is one to 1.3 feet. Chlorophyll *a* concentrations are high in the Caloosahatchee River, and range from medium to hypereutrophic in Charlotte Harbor, maximums occurring periodically in the summer, with light, nitrogen and phosphorus being the limiting factors. Nutrients are high in the river and range from low to high in the harbor, where nuisance and toxic algal blooms also occur episodically from April to June. Hypoxia occurs in bottom waters of both the river and harbor periodically during the summer months. Anoxic conditions in Charlotte Harbor have been observed in all zones. The planktonic community in the harbor is dominated by blue-green algae in the tidal fresh zone, flagellates and diatoms in the mixing zone, and diatoms in the seawater zone; the benthic community is dominated by annelids, except in the seawater zone where it is more diverse. Sub-merged aquatic vegetation coverage is low both in the river and harbor areas; total salt marsh for the harbor is approximately 6,800 acres.

Sarasota Bay: This is an elongated bar-built coastal lagoon with an average depth of 6.4 feet and a tidal range of 1.3 feet. The majority of the freshwater inflow is from several small tributaries and storm-water drains. The salinity structure is determined by seasonal patterns of precipitation and evaporation, while wind and tides influence the bay's circulation. Turbidity levels are moderate, while chlorophyll *a* concentrations are considered to be high, particularly in the summer, nitrogen being the limiting factor. Nutrients are moderate to high, and nuisance and toxic algal blooms have been observed, the latter particularly in the seawater zone. Anoxia and hypoxia in bottom waters occur periodically from June to September. The planktonic community is dominated by diatoms and flagellates, and the benthic community by annelids. Submerged aquatic vegetation coverage is medium and has been on the increase, probably due to changes in non-point sources.

Tampa Bay: Tampa Bay is a large Y-shaped estuary consisting of Tampa Bay proper, and Old Tampa and Hillsborough bays. Major rivers discharging into the bay are the Little Manatee, Alafia, Manatee, Palm and Hillsborough, with flows from the latter three artificially controlled. Widely spaced barrier islands front the Tampa Bay system. The average depth of the estuary is 12.8 feet, and the tidal range is 2.2 feet at Egmont Key. A well-defined salinity gradient is established by the free exchange and circulation of Gulf water. However, circulation of the bay has been altered by dredged channels, disposal sites, major causeways and shoreline landfills. Chlorophyll *a* ranges from medium to hypereutrophic, with maximums occurring periodically from June to October, nitrogen and light being the limiting factors. Nuisance blooms of blue-green algae and dinoflagellates occur in the summer in the seawater zone, as do toxic blooms of *Gymnodinium breve*. The planktonic community is dominated by diatoms; the benthic community is diverse in some areas and dominated by annelids in others. Lower Tampa Bay contains some submerged aquatic vegetation, which is on the increase, and about half of its eastern shore is dominated by mangrove forests. Mangroves and salt marshes also are found in portions of Old Tampa Bay, while much of the remaining shoreline has been developed.

Big Bend/Panhandle Coast Estuaries: This region encompasses approximately 1,588 square miles of water surface area. The Big Bend area of this region has a rugged shoreline with wide, shallow pools and expansive areas of freshwater and tidal marshes. Freshwater inflow is dominated by the Suwannee River. The tidal range in the Big Bend area is approximately 3.5 feet. Estuaries of the Florida Panhandle consist mainly of smooth, sandy beaches and well developed dune systems, with the coastline partially enclosed by barrier islands. Protected bays located here have high discharge rates from freshwater sources. The tidal range along the Panhandle is 1.5 to 2.0 feet.

Suwannee River: This system consists of Suwannee Sound, the Suwannee River delta, and extensive wetland areas. The average depth of the estuary is 4.6 feet. Salinity variability is most pronounced in Suwannee Sound where tides are a dominant influence and range approximately three feet. This system is characterized as having chlorophyll *a* concentrations from low to medium, with maximum concentrations occurring periodically from May to September, the limiting factor being nitrogen. Turbidity levels in the seawater zone are moderate; nutrients levels are moderate to high. Although there are no nuisance algal blooms, toxic blooms are known to occur episodically. Anoxia and hypoxia are not a problem in the estuary. The planktonic community is dominated by diatoms; the benthic community is dominated by aquatic insects in the tidal fresh zone, but is considered to be diverse in other areas. Submerged aquatic vegetation coverage ranges from low to medium, while salt marsh cover is approximately 20,900 acres.

Apalachee Bay to Anclote Key: The estuary system between Apalachicola Bay and Anclote Key (just above Tampa Bay) contrasts sharply with the panhandle estuaries to the west. The estuarine system along this stretch of the coast does not conform to the classic definition of an estuary - it is an open water system, not semi-enclosed, nor is it separated from a major water body by barrier islands. There are no upland hills and valleys creating inland bays and, as there are no barrier islands, there is nothing to impede stream flow to form drowned valleys. Instead, there is an extremely broad zone of fresh and salt water mixing over the continental shelf with a gentle gradient of about 0.4 meter per 12.6 km (1.5 feet per mile) offshore. Salinity ranges from near zero to about 32 ppt. The periphery of Apalachee Bay is lined by many small estuaries, streams, lakes and freshwater marshes. Nevertheless, the near shore flora and fauna are characteristically estuarine. Freshwater discharge to this area is from several rivers that drain the region, with the salinity structure influenced primarily by the Econfina, Fenholloway, and Ochlockonee rivers. The tidal range is 2.1 feet near the entrances to these major rivers. Bottom sediments usually consist of mud and muddy sand. Chlorophyll *a* and nutrient concentrations within the system are generally low to medium, while turbidity is medium to high. Although nuisance algal blooms have not been observed, toxic blooms occur in the seawater zone. The phytoplankton community is dominated by diatoms; the benthic community is dominated by annelids in the tidal fresh zone, but is diverse elsewhere. Submerged aquatic vegetation coverage ranges from very low to high, and is reported to be on the increase. Salt marshes within the Apalachee Bay drainage area total approximately 24,400 acres.

Apalachicola Bay: The Apalachicola Bay system is a broad, shallow lagoonal system consisting of the bay proper and several smaller embayments. It is separated from the Gulf of Mexico by three barrier islands. The primary source of freshwater inflow is the Apalachicola River, which determines the salinity structure in the bay. The annual cyclic flows of the Apalachicola River are inversely proportional to salinity in the bay, which ranges from near zero to about 32 ppt. The cyclic flow of the river is an important factor concerning primary productivity. Chlorophyll *a* concentrations range from low to medium, with maximums seen from December to April. Turbidity in the mixing and seawater zones is medium to high. Although nuisance algal blooms do not occur, toxic blooms occur in the seawater zone episodically from June to October. Low dissolved oxygen conditions occur in bottom waters periodically, and also from June to October. Bottom sediments consist chiefly of clays transported by the Apalachicola Rive; the benthic community is dominated by annelids, except in the mixing zone where it is diverse. Some portions of the bay consist of hard muds that support large oyster reefs. The planktonic community is dominated by diatoms. Submerged aquatic vegetation coverage is low; salt marshes total 17,000 acres.

St. Andrew Bay: The St. Andrew Bay system is a relatively deep - average depth is 11.9 feet - Y-shaped embayment that consists of four drowned stream basins: St. Andrew, East, North, and West bays, the depths of which are 5.2, 2.1, 1.7 and 2.0 meters, respectively. Minimal freshwater is supplied by Econfina and Bear creeks, the former being the primary influence on the salinity structure of the bay. Like other north Florida estuaries, nearshore areas are predominantly sand with silts and clays found in the center. Salinity within the system varies greatly, but is generally 18 to 33 ppt. The tidal range is 1.3 feet near West Pass. Chlorophyll *a* concentrations are considered to be medium, with maximums occurring periodically during the summer, associated with point and non-point sources. Turbidity and nutrients are moderate, reaching highest concentrations in the spring and summer. Nuisance and toxic algal blooms occur episodically in the summer, as do hypoxia and anoxia in bottom waters. The planktonic community is dominated by diatoms; the benthic community is dominated by annelids in the mixing and seawater zones. Submerged aquatic vegetation coverage is low; salt marshes cover approximately 8,500 acres.

Choctawhatchee Bay: This is a relatively deep and narrow lagoon consisting of the Choctawhatchee Bay and river delta and several smaller embayments, separated from the Gulf of Mexico by a barrier spit along the south shore. Average depth of the estuary is 14.2 feet. Salinity varies from zero near the Choctawhatchee River delta to about 30 ppt near Destin East Pass, the only outlet to the Gulf. Extreme stratification has been reported for the eastern portion of the Bay. The tidal range is about 0.6 feet near East Pass. Sediments around the Bay's periphery to about 800 m offshore, and in water no deeper than two meters, is medium-grade sand. The center of the bay is characterized by very fine, clay-size sediment transported to the Bay through the Choctawhatchee River, while in the western portion of the bay there is a lack of fine sediment cover over reworked sand sediment. Turbidity ranges from medium to high, while chlorophyll *a* concentrations are considered to be medium, phosphorus being the limiting factor.

Elevated nutrient concentrations, which are attributed to non-point sources, occur throughout the year in the tidal fresh zone and from May to September in the mixing zone. Nuisance and toxic algal blooms occur periodically during the summer. Both hypoxia and anoxia are observed, especially in the tidal fresh and mixing zones, occurring mostly in bottom waters from June to October, and due primarily to water column stratification. The planktonic community is dominated by diatoms in the mixing and seawater zone, while the benthic community is diverse, except in the tidal fresh zone, where it is dominated by annelids. Submerged aquatic vegetation are found in certain portions of this area, overall coverage being low. Salt marshes cover approximately 2,700 acres.

Pensacola Bay: The Pensacola Bay system is a drowned river estuary and lagoon, consisting of Pensacola, Escambia, East, and Blackwater bays and Santa Rosa Sound, separated from the Gulf of Mexico by Santa Rosa Island. The average depth of the estuary is 12.7 feet.; the tidal range 3.2 feet near the mouth of the bay. Low tidal amplitude and frequency, and relatively low river discharge are responsible for the low flushing rate (one complete turnover every 18 days). The salinity structure is determined by seasonal freshwater discharge, primarily from the Escambia River; salinity varies from zero near the headwaters to 30 ppt near the inlet. Fine to coarse sands, sometimes mixed with clays, are found in shallows near the shorelines, but fine alluvial clays cover most of the bay bottom. The system is characterized as having a wide range of chlorophyll *a* concentrations - from low to hypereutrophic - with increases over the last few years in the mixing zone being attributed to point and non-point sources. Nutrients range from low to high, with elevated concentrations occurring throughout the year in Bayou Texar and in March and April elsewhere. Nuisance and toxic algal blooms are not known to occur, and although anoxic conditions have not been observed, hypoxia occurs periodically in the Escambia River and in the mixing zone. Although the planktonic community is generally diverse, the benthic community shows a diversity of organisms only in the seawater zone, and is dominated by aquatic insects in the tidal zone and by annelids in the mixing zone. Submerged aquatic vegetation coverage is very low; salt marsh coverage within the drainage basin is approximately 6,700 acres.

Perdido Bay: This is a small system consisting of Perdido Bay and several small creeks. It is separated from the Gulf of Mexico by Perdido Key, Perdido Pass being the only area where direct exchange with the Gulf occurs. The vertical salinity structure is determined by seasonal discharge from the Perdido River, and also by deep areas that trap saline bottom waters. The average depth of the estuary is 6.9 feet; the tidal range within the bay is approximately 1.6 feet. Within the system, chlorophyll *a* and nutrient concentrations range from low to medium, higher levels occurring periodically in the spring and summer, with light the limiting factor in the tidal fresh zone and nutrients in the mixing and seawater zones. Elevated nitrogen and phosphorus concentrations are seen from April to October, and nuisance and toxic algal blooms occur during the summer. Anoxia and hypoxia are seen periodically from June to October in bottom waters, water column stratification being a significant factor for these conditions. Turbidity is medium to high throughout the year. Although the planktonic community is generally diverse, diversity of organisms in the benthic community is seen only in the seawater zone, with aquatic insects and annelids dominating the tidal fresh and mixing zones, respectively. Submerged aquatic vegetation coverage ranges from none to low, while salt marsh covers approximately 1,900 acres.

Mobile Bay: Mobile Bay is a drowned river valley estuary consisting of the main bay, Mobile River, Tensaw River and small embayments. The average depth of the estuary is 9.9 feet. The salinity structure of the bay is determined by the Mobile River, and is moderately stratified throughout the year. The tidal range is 1.3 feet near Main Pass. While turbidity is moderate to high, chlorophyll *a* concentrations in the bay are moderate, maximum concentrations occurring periodically from April to September in the mixing zone and from December to May in the seawater zone, limiting factors being nitrogen and phosphorus. Nutrients range from low to medium, with elevated concentrations seen throughout the year in the tidal fresh zone, and from January to May in the seawater zone. Although nuisance algal blooms do not occur, toxic blooms are reported from October to December. Hypoxic and anoxic conditions occur periodically from July to October in bottom waters. Tidal marshes are found in the north end of the bay and along Dog, Deer and Fowl Rivers, and along the shorelines of Weeks, Oyster and Bon Secour Bays and Little Point Clear. The total area of salt marshes is approximately 17,000 acres.

Mississippi Delta/Louisiana Coast Estuaries: Estuarine systems in this region encompass approximately 5,791 square miles of water surface area, plus the Mississippi/Atchafalaya River Plume, totaling 12,256 square miles. The entire Mississippi Delta area is greatly affected by the Mississippi River and indirectly by the Atchafalaya River; significant inflows from these and other small coastal rivers cause reduced salinities and density gradients near the estuary mouths. The coastal environment is characterized by shallow, turbid embayments and extensive marsh systems. The drainage patterns have been highly altered by man-made channels. Coastal Louisiana is predominately a broad marsh indented by shallow bays containing innumerable valuable nursery areas. These waters are generally shallow with over half between zero and 1.8 m (6.0 feet) in depth. Sediments consist of mud, sand and silt and are very similar across the coast, ranging from coarse near the Gulf and barrier islands to fine in the upper estuaries.

Mississippi Sound: Mississippi Sound is a system of estuaries adjoining a lagoon. The sound, separated from the Gulf of Mexico by a chain of barrier islands, acts as a mixing basin for freshwater discharge from rivers and seawater entering through the barrier island passes. The circulation in the central Mississippi Sound is greatly influenced by tidal flux through Dog Keys and Ship Island Passes. The primary source of freshwater is Bay St. Louis. The western end of Mississippi Sound is heavily influenced by drainage from the Pearl River, the Lake Borgne-Lake Pontchartrain complex, and Bay St. Louis. Silt clay is the dominant sediment in the sound. The salinity regime of the eastern Mississippi Sound is determined largely by the influx of Gulf waters through Petit Bois, Horn, and Dog Keys Passes and the outflow of waters from Mobile Bay, the Pascagoula River, and Biloxi Bay. Both north-south and east-west salinity gradients exist in addition to vertical gradients. Seasonally, salinities are lowest in the early spring, rise sporadically through the summer, and peak in the fall. Temporary oxygen depletion may occur in deep holes and behind sills in river channels. Anoxia, resulting from excessive biological oxygen demand, occurs periodically in waters near heavily populated areas and in waters subject to industrial outfalls. In some years, the presence of Yucatan Loop waters has been detected near the barrier islands. This water mass, which is characterized by high salinity, below average temperature and extremely low levels of dissolved oxygen, may remain in the area through the late summer months and at times penetrate into Mississippi Sound near the Island passes. Nutrients in the system are considered to be low to medium; nuisance algal blooms are also known to occur episodically in January and February, and toxic blooms are seen from July to September. Submerged aquatic vegetation coverage is generally very low, while salt marshes cover approximately 170,600 acres.

Lake Borgne: Lake Borgne has an area of 272.1 square miles with an average depth of 9.5 feet.; it drains an area of 7,790 square miles. The average daily freshwater inflow is 25,100 cfs, mainly from the Pearl River. Salinity has been altered since construction of the Mississippi River-Gulf outlet and other channels connecting the lake with Breton and Mississippi Sounds. High turbidity and low coverage of submerged aquatic vegetation are features of this system. The planktonic community is diverse; the benthic community is dominated by annelids. Anoxia or hypoxia have not been observed in this area.

Breton and Chandeleur Sounds: This area is located in the Mississippi deltaic plain, and consists of many small embayments and tidal marshes separated from the Gulf of Mexico by a chain of barrier islands (Chandeleur Islands). The average depth is 8.9 feet. The surface area is 1,662.4 square miles with a little more than half being seawater (salinity > 25 ppt). The freshwater inflow is mainly from the Pearl River through Lake Borgne at an average daily rate of 10,300 cfs. While nitrogen is low, phosphorus concentrations are high in the nearshore areas. Turbidity is high or medium in most parts of the sounds. Anoxia and hypoxia occur in bottom waters of the seawater zone from July to September, causing biological stress to the benthic communities. Submerged aquatic vegetation coverage is limited to some shallow areas and is declining.

Mississippi River: The Mississippi River has an extended estuarine system consisting of a delta area, small embayments and tidal marshes. The surface area is 378.3 square miles with a drainage area of 1,846 square miles. The average depth of the estuary is 23.1 feet. As the largest single freshwater source in the United States, the Mississippi River provides freshwater inflow at an average daily rate of 464,400 cfs, as well as large quantities of nutrients to the estuaries throughout the entire Louisiana and Texas coast. The salinity in most areas ranges between 0.5 to 25 ppt, with the upper tidal areas being freshwater (< 0.5 ppt). Nitrogen and phosphorus concentrations are high throughout the estuary. Chlorophyll *a* concentrations are low in the tidal freshwater areas and medium in the saline water. High turbidity prevails in the whole area and occurs all year, which is the limiting factor of primary productivity. Anoxia and hypoxia have not been observed even though water column stratification occurs from July through September. The benthic community is dominated by annelids and crustaceans. Submerged aquatic vegetation is virtually absent in this system. However, in the delta region there are approximately 1,042,900 acres of salt marsh.

Barataria Bay: Barataria Bay is an estuarine-wetland system located at the southwest side of the Mississippi River deltaic plain, covering an area of 359.2 square miles with an average depth of 4.5 feet. The average daily inflow is 5,500 cfs. About 30 percent of the system has salinity below 0.5 ppt. The lower portion consists of Caminada and Barataria Bays with shallow, wide areas of open water interspersed with numerous marsh islands. The upper portion is composed of tidal marshes separated by tidal creeks, bayous and shallow lakes. An extensive network of small navigation channels and drainage canals has significantly altered the hydrology of the bay. Seasonal advection from the Mississippi River and precipitation are the main sources of freshwater. This system is highly eutrophic, and turbidity is also high. High concentrations of nitrogen, phosphorus and chlorophyll *a* occur throughout the year, and nuisance blue-green algae are persistent in the upper portion of the system. Anoxia and hypoxia occur from June to September. The planktonic community is dominated by blue-green algae; the benthic community is diverse with annelids dominant in the lower portion of the system. Submerged aquatic vegetation coverage ranges from low to medium.

Terrebonne/Timbalier Bay: This system is located in the Mississippi River deltaic plain, covering an area of 515.2 square miles. The average depth is 4.7 feet. The upper portion of the system is composed of tidal marshes separated by tidal creeks, bayous and shallow lakes, although historically, salt marshes have declined due to watershed alterations. Seasonal advection from the Mississippi River and precipitation are the main sources of freshwater; the average daily inflow is 4,600 cfs. Salinity ranges from 0.5 to 25 ppt. High eutrophication is a feature of this system. Nitrogen concentration is medium, but is on the increase, while phosphorus and chlorophyll *a* concentrations are high, nitrogen, phosphorus and silica being the limiting factors. Nuisance and toxic algae occur episodically in this area. However, anoxia and hypoxia have not been observed. Both the planktonic and benthic communities are considered to be diverse. Submerged aquatic vegetation coverage is low, and salt marshes have declined due to watershed alterations.

Atchafalaya/Vermillion Bays: This system consists of four major water bodies, numerous bayous, locks, and canals. The whole estuarine area is 832.6 square miles. The average depth is 6.5 feet. The primary sources of freshwater are from Atchafalaya and Vermilion Rivers, with an average daily inflow rate of 223,800 cfs. Eutrophication prevails in this system. Nutrients, chlorophyll *a* concentrations and turbidity are all high, largely due to non-point source pollution. Nuisance and toxic algal species occur in the lower portion. Anoxia and hypoxia occur in the Atchafalaya River from June to October when the water column stratifies. Blue-green algae dominate the planktonic community; the benthic community is dominated by arthropods, molluscs, or annelids depending on the location. Submerged aquatic vegetation coverage is high in the upper freshwater areas, but is decreasing due to the introduction of non-indigenous *Hydrila*. Salt marshes cover approximately 126,500 acres.

Mermentau River: The Mermentau River extends from the mouth of the estuary at the Gulf of Mexico to the head-of-tide at the Catfish Point Control Structure near Grand Lake. The estuarine surface area is seven square miles, and the average depth 3.9 feet. Freshwater inflow is mainly from Grand Lake, but the discharge is regulated, causing salinity to fluctuate in response to periodic control structure releases. The average daily inflow is 4393 cfs. Nitrogen concentration is moderate, while phosphorus and turbidity are high, the latter particularly high during the winter. Nuisance algal blooms, anoxia and hypoxia have not been observed. Submerged aquatic vegetation is absent from this system.

Calcasieu Lake: The Calcasieu Lake estuary consists of Calcasieu Lake and several secondary embayments. The entire area is 99.7 square miles, with an average depth of 9.4 feet. This estuary receives the majority of its freshwater from the Calcasieu River at an average daily rate of 6,300 cfs. In Calcasieu Lake, both nitrogen and phosphorus concentrations range from medium to high, with elevated conditions seen from March to May. High turbidity occurs in the summer. Chlorophyll *a* concentrations are high, with maximums occurring from February through April, nitrogen being the limiting factor. Nuisance and toxic algal blooms occur periodically in the summer. Anoxia and hypoxia occur in the lake bottom, but this condition has improved in recent years due to point source pollution control. The planktonic and benthic communities are generally diverse. Submerged aquatic vegetation coverage is low and decreasing, primarily due to alterations to the watershed and to point sources of pollution. The extent of salt marsh is approximately 82,600 acres.

Sabine Lake: The Texas/Louisiana border divides Sabine Lake, a broad, shallow open bay with a narrow, deep channel on the west side. It is connected to the Gulf of Mexico by Sabine Pass. The average depth of the estuary is 8.2 feet, while the main navigation channel is 36 feet, significantly influencing circulation and salinity patterns. An average of 17,200 cfs of fresh water flows into the bay annually, primarily from the Sabine and Neches Rivers. Salinity ranges from zero to 20 ppt in upper Sabine Lake and 20 to 30 ppt in Sabine Pass. The bay bottom consists primarily of mud and silt. The western portion of the bay is heavily industrialized, and most of the marsh vegetation is found on the eastern side. A few small oyster reefs are found in the southern portion. Chlorophyll *a* and nutrient levels are moderate, while turbidity is high throughout the year. Nuisance algal blooms occur episodically from May to July, probably due to non-point sources; however, there are no toxic blooms. Hypoxia has been observed periodically from July to August in bottom waters, water column stratification believed to be a moderate contributing factor. Depending on the location, the plankton community is dominated by blue-green algae or diatoms; the benthic community is diverse or dominated by mollusks. Submerged aquatic vegetation coverage is considered to be very low; salt marsh covers approximately 110,000 acres.

Texas Coast Estuaries: The shoreline of this region is dominated by large bays, lagoons and barrier islands. The estuaries, which encompass approximately 2,565 square miles of water surface area, are typically bordered by tidal marshes and mud-sand flats. Freshwater discharge is primarily from the Trinity, Brazos and Guadelupe river systems, although direct precipitation contributes significantly to the total freshwater inflow. The presence of barrier islands, however, coupled with low runoff and high evaporation rates, produces hypersaline conditions in these estuaries, especially in the summer. The tidal range for the region is from 0.5 to 1.5 feet.

Galveston Bay: Galveston Bay contains 540 square miles of water surface area, and is the largest estuary in Texas. The Galveston Bay system includes Galveston, Trinity, East, West, Dickinson, Chocolate, Christmas, Bastrop, Dollar, Drum, and Tabbs Bays and Clear, Moses, and Jones Lakes. The average depth of the estuary is 6.2 feet. However, ship channels leading from the Gulf of Mexico into Houston, Texas City, Galveston, and Bayport are dredged to a depth of approximately 40 feet. The bay is separated from the Gulf of Mexico by Fallets Island, Galveston Island and Bolivar Peninsula. The primary source of freshwater inflow is the Trinity and San Jacinto Rivers. Salinity generally ranges from five to15 ppt in the upper portion of the bay to 20 to 30 ppt in the lower bay. One man-made pass and two natural passes connect the estuary with the Gulf. Chlorophyll *a* concentrations are considered to be low to medium within the system and turbidity ranges from medium to high. Nutrients are elevated from April to October in the tidal fresh zone and from May to December in the mixing zone. In lower Galveston Bay nutrients levels are moderate. Nuisance and toxic blooms are noted in the summer. Both hypoxia and anoxia occur during the summer in bottom waters of the tidal fresh and mixing zones, due to some extent to water column stratification. In both of these zones, the benthic community is dominated by annelids. There has been a decrease in submerged aquatic vegetation due to watershed alterations and physical disturbances. Salt marshes cover approximately 94,900 acres.

Matagorda Bay: This is a broad, shallow lagoonal system separated from the Gulf of Mexico by the Matagorda Peninsula. Water exchange is through Pass Cavallo and a man-made ship channel. The Colorado River formed a delta that divides the bay into Matagorda Bay proper and east Matagorda Bay. Water exchange with the Gulf of Mexico to the eastern portion is through Brown Cedar Cut, which periodically closes due to climatic conditions. Other major bays making up the Matagorda system are Tres Palacios, Carancahua, and Lavaca Bays. The average depth of the Matagorda system is about seven feet; bottom substrate is sand, shell, silt, and clay. Freshwater inflow into Matagorda Bay is primarily from the Tres Palacios, Carancahua, Lavaca and Navidad Rivers. Partial flow comes from the Colorado River, which was diverted to empty directly into the Gulf of Mexico. Vertically homogeneous conditions commonly exist in the open bay. The bay is characterized as having low to hypereutrophic chlorophyll *a* levels, maximums occurring periodically from March to August, with light and nitrogen the limiting factors. Turbidity and nutrient levels are generally high throughout the year; elevated nitrogen and phosphorus levels in the seawater zone are seen from April to July and also in October and November. Nuisance and toxic algal blooms are also observed in the summer and fall. Hypoxic conditions occur episodically from August to October in bottom waters, due largely to water column stratification. The planktonic community is largely dominated by flagellates and diatoms, and the benthic community by annelids. Submerged aquatic vegetation coverage is low, but is increasing. Salt marshes cover approximately 43,500 acres.

San Antonio Bay: The San Antonio Bay system, comprised of Espiritu Santo, San Antonio, Guadalupe, Itynes, Mesquite, and Ayers bays, and Mission Lake, covers some 205 square miles at mean low water. Freshwater inflow is provided mainly by the Guadalupe and San Antonio Rivers. Salinity ranges from 0.0 to 8.0 ppt in the upper bay to 14.0 to 21.0 ppt in the lower portion. The system is separated from the Gulf of Mexico by Matagorda Island. Water exchange is through Pass Cavallo (located in Matagorda Bay) and Cedar Bayou Pass (located in Mesquite Bay). The average depth of bay is about 4.3 feet; substrates generally consist of mud, sand and shell. Chlorophyll *a* concentrations range from low to high, with nitrogen and phosphorus the limiting factors. Turbidity is high, probably due to point and non-point sources. High nutrient concentrations occur throughout the year in the tidal fresh zone and from November to March in the mixing zone. Hypoxia occurs episodically in bottom waters, a significant factor being water column stratification. The planktonic and benthic communities are diverse. Submerged aquatic vegetation coverage is low and on the decrease, due to point and non-point sources. Salt marshes within the system cover approximately 32,900 acres.

Aransas Bay: The Aransas Bay complex, which comprises Copano, St. Charles, Dunham, Port, Mission and Aransas Bays, covers approximately 208 square miles. It is separated from the Gulf of Mexico by San Jose Island, with water exchange through Aransas Pass and Cedar Bayou Pass. Bottom sediments consist of mud, sand and shell; average depth for the system is approximately 5.3 feet. Freshwater inflow to the system tends to be from isolated pulses during high flow months, which depresses salinities within Copano Bay. The existence of oyster reefs across Copano Bay impedes circulation and affects salinity patterns in the upper estuary. Chlorophyll *a* concentrations in the Bay range from medium to high, with nitrogen the limiting factor, and turbidity is high. Nutrient concentrations range from low to moderate, with elevated nitrogen levels from November to May and high phosphorus throughout the year in the mixing zone, showing increasing trends. The increases are due primarily to non-point sources. Although anoxia and hypoxia do not occur, nuisance and toxic algal blooms occur episodically in the summer in the mixing zone, and toxic algal blooms occur in the fall in the seawater zone. Submerged aquatic vegetation ranges from very low in the mixing zone to moderate in the seawater zone; salt marshes cover approximately 30,700 acres.

Corpus Christi Bay: Corpus Christi Bay is a bar-built system comprised of Redfish, Corpus Christi, Nueces, and Oso Bays, containing 192 square miles of water surface area with an average daily inflow of 1,200 cfs. The average depth of the estuary is 7.8 feet. The bay is separated from the Gulf of Mexico by Mustang Island, with water transfer through Aransas Pass and the Corpus Christi Water Exchange Pass. Bottom sediments consist of mud, sand and silt. Evaporation is the dominant influence on salinity structure, and salinities in the bay can reach hypersaline levels, especially near Laguna Madre. While turbidity is high throughout the year, nutrient levels range from low to high. Chlorophyll *a* concentrations are medium to high (periodically) from February to October in the mixing and seawater zones, with the limiting factor being nitrogen. Nuisance and toxic algal blooms occur in both the mixing and seawater zones. Although hypoxia occurs in seawater zone bottom waters periodically from June to August, anoxia has not been observed. Within the various zones, the planktonic community ranges from one dominated by blue-green algae and diatoms to one that is generally diverse. The benthic community is dominated by annelids in the mixing and seawater zones. Submerged aquatic vegetation ranges from low coverage to being absent; salt marshes cover approximately 12,200 acres within the watershed.

Laguna Madre/Baffin Bay: This area is one of mud-sand flats inundated by wind-driven flows. Direct precipitation contributes approximately 65 percent of the total freshwater inflow to the system. However, the salinity structure is determined by isolated pulses and intense evaporation rather that seasonal freshwater discharges. The Baffin Bay system consists of Alexin Bay, Capo del Inferno, Laguna Salad, and Capo del Grail. The average depth is 4.2 feet. No major rivers drain into the Laguna Madre, and the area is generally hypersaline. Both Upper and Lower Laguna Madre are bar-built coastal lagoons separated from the Gulf of Mexico by Padre Island. The average depth is 2.5 feet. Lower Laguna Madre, including the South Bay and La Barilla Grande complex, contains 366 square miles of water surface area. Water transfer is through Bravos Santiago Pass and Port Mansfield Pass to the south and passes in Corpus Christi Bay to the north. Bottom sediments consist of mud, silt, sand and quartzose (sand-small rocks). The only natural oyster reefs in Laguna Madre are in South Bay, the southernmost area of the lagoon. Chlorophyll *a* within this system ranges from medium to hypereutrophic, with nitrogen the limiting factor. Turbidity is high and is attributed largely to "brown tides"; these and other nuisance algal blooms are persistent throughout the year and are associated primarily with non-point sources. Hypoxia is observed periodically in the system during the summer, while anoxia occurs only in bottom waters of Lower Laguna Madre, from June to September. Although nutrient levels are generally low in Upper Laguna Madre, they are elevated throughout the year in other portions of the system. Depending on the area, the planktonic community is dominated by blue-green algae, flagellates, and diatoms. The benthic community is diverse in some areas, and dominated by annelids in others. Submerged aquatic vegetation coverage is low but on the increase in Baffin Bay, but high in Upper and Lower Laguna Madre. Salt marsh coverage is approximately 67,800 acres.

5.4.3 U.S. Caribbean

The waters of the Caribbean region include the coastal waters surrounding the U.S. Virgin Islands and Puerto Rico. The marine habitats found within the region are the products of, and key factors shaping, local terrestrial, geological, and hydrological regimes. The territory of the U.S. Virgin Islands includes roughly 63 islands, the largest of which are St. Thomas (83 square km or 32 square miles), St. John (52 square km or 20 square miles), and St. Croix (207 square km or 80 square miles). The commonwealth of Puerto Rico includes many islands, the largest of which is Puerto Rico. To the south lie numerous cays covered with sand, coral, and mangroves. To the west lie Mona, Monito, and Desecheo Islands. To the northeast lies the chain of islands called La Cordillera. To the southeast lies Vieques Island. All of these Caribbean islands, with the exception of St. Croix, are part of a volcanic chain of islands formed by the subduction of one tectonic plate beneath another. Tremendously diverse habitat (rocky shores, sandy beaches, mangroves, seagrasses, algal plains, and coral reefs) and the consistent light and temperature regimes characteristic of the tropics are conducive to high species diversity (Appledoorn and Meyers, 1993).

The waters of the Florida Keys and southeast Florida are intrinsically linked with the waters of the Gulf of Mexico and the waters of the Caribbean to the west, south, and east, and to the waters of the South Atlantic Bight to the north. These waters represent a transition from insular to continental regimes and from tropical to temperate regimes. This zone, therefore, contains one of the richest floral and faunal complexes.

Insular Shelf/Slope Features

(Material in this section is largely a summary of information in Appeldoorn and Meyers, 1993. Original sources of information are referenced in that document.)

Puerto Rico and the U.S. Virgin Islands contain a wide variety of coastal marine habitats, including coral and rock reefs, seagrass beds, mangrove lagoons, sand and algal plains, soft bottom areas, and sandy beaches. These habitats are, however, very patchily distributed. Nearshore waters range from zero to 20 m in depth, and outer shelf waters range from 20 to 30 m in depth, the depth of the shelf break. Along the north coast the insular shelf is very narrow (two to three km wide), seas are generally rough, and few good harbors are present. The coast is a mixture of coral and rock reefs, and sandy beaches. The east coast has an extensive shelf that extends to the British Virgin Islands. Depth ranges from 18 to 30 m. Much of the bottom is sandy, commonly with algal and sponge communities. The southeast coast has a narrow shelf (eight km wide). About 25 km to the southeast is Grappler Bank, a small seamount with its summit at a depth of 70 m. The central south coast broadens slightly to 15 km and an extensive seagrass bed extends nine kilometers offshore to Caja de Muertos Island. Further westward, the shelf narrows again to just two km before widening at the southwest corner to over ten kilometers. The entirety of the southern shelf is characterized by hard or sand-algal bottoms with emergent coral reefs, grassbeds, and shelf edge. Along the southern portion of the west coast the expanse of shelf continues to widen, reaching 25 km at its maximum. A broad expanse of the shelf is found between 14 and 27 meters where habitats are similar to those of the south coast. To the north, along the west coast, the shelf rapidly narrows to two to three kilometers.

Physical Oceanography (Water Movements and Marine Habitats)
(Material in this section is largely a summary of information in Appeldoorn and Meyers, 1993. Original sources of information are referenced in that document.)

Hydrologic patterns link the waters of the U.S. Caribbean with the Florida Keys and southeast Florida. The marine waters of the U.S. Caribbean are primarily influenced by the waters of the westward flowing North Equatorial Current, the predominant hydrological driving force in the Caribbean region. It flows from east to west along the north boundary of the Caribbean plateau and splits at the Lesser Antilles, flowing westward along the north coasts of the islands. North of the Mona Channel it splits, with one branch flowing north of Silver and Navidad Banks, past Turks and Caicos to form the Bahamas Current. The southern branch stays along the north coast of Hispañiola about 30 km offshore. A small gyre has been documented off the northwest corner of Puerto Rico, resulting in an easterly flow nearshore in this area.

The north branch of the Caribbean Current flows west into the Caribbean Basin at roughly 0.5 m (1.7 feet) per second. It is located about 100 km south of the islands, but its position varies seasonally. During the winter it is found further to the south than in summer. Flow along the south coast of Puerto Rico is generally westerly, but this is offset by gyres formed between the Caribbean Current and the island. The Antilles Current flows to the west along the northern edge of the Bahamas Bank and links the waters of the Caribbean to those of southeast Florida.

Several rivers, including the Amazon, the Orinoco, the Magdelana, and the Columbian, exert intermittent but important influence on the waters of the Caribbean Basin. The plume from the Orinoco River, which flows up the Lesser Antilles and along the Greater Antilles, for example, can carry with it high concentrations of suspended particles, unique chemical properties, and biota to near the south coast of Puerto Rico. The plume, therefore, can be responsible for events of high turbidity and algal blooms that usually occur in the Caribbean Basin in October.

Coastal surface water temperatures remain fairly constant throughout the year and average between 26° and 30°C. Salinity of coastal waters is purely oceanic and so is usually around 36 ppt. However, in the enclosed or semi-enclosed embayments salinity may vary widely depending on fluvial and evaporational influences.

It is believed that no up-welling occurs in the waters of the U.S. Caribbean (except perhaps during storm events) and, since the waters are relatively stratified, they are severely nutrient-limited. In tropical waters nitrogen is the principal limiting nutrient.

Coastal and Estuarine Habitats
(Material in this section is largely a summary of information in Appeldoorn and Meyers, 1993. Original sources of information are referenced in that document.)

Although the U.S. waters of the Caribbean are relatively nutrient poor, and therefore have low rates of primary and secondary productivity, they display some of the greatest diversity of any part of the south Atlantic region. High and diverse concentrations of biota are found where habitat is abundant. Coral reefs, seagrass beds, and mangrove ecosystems are the most productive of the habitat types found in the Caribbean, but other areas such as soft-bottom lagoons, algal hard grounds, mud flats, salt ponds, sandy beaches, and rocky shores are also important in overall productivity. These diverse habitats allow for eclectic floral and faunal populations.

Offshore, between the seagrass beds and the coral reefs and in deeper waters, sandy bottoms and algal plains dominate. These areas may be sparsely or densely vegetated with a canopy of up to one meter of red and brown algae. Algal plains are not areas of active sand transport. These are algae-dominated sandy bottoms, often covered with carbonate nodules. They occur primarily in deep water (> 15 m or 50 feet) and account for roughly 70 percent of the area of the insular shelf of the U.S. Virgin Islands. Algal plains support a variety of organisms including algae, sponges, gorgonians, solitary corals, molluscs, fish, and worms, and may serve as critical juvenile habitat for commercially important (and diminishing) species such as queen triggerfish and spiny lobsters.

Coral reefs and other coral communities are some of the most important ecological (and economic) coastal resources in the Caribbean. They act as barriers to storm waves and provide habitat for a wide variety of marine organisms, including most of the economically important species of fish and shellfish. They are the primary source for carbonate sand, and serve as the basis for much of the tourism. Coral communities are made by the build up of calcium carbonate produced by living animals, coral polyps, in symbiosis with a dinoflagellate, known as zooxanthellae. During summer and early fall, most of the coral building organisms are at or near the upper temperature limit for survival and so are living under natural conditions of stress. Further increase in local or global temperature could prove devastating.

Seagrass beds are highly productive ecosystems that are quite extensive in the Caribbean; some of the largest seagrass beds in the world lie beyond the shore on both sides of the Keys. Seagrass beds often occur in close association with shallow-water coral reefs. Turtle grass (*Thalassia testudinium*), manatee grass (*Syringodium filiforme*), and shoal grass (*Halodule wrightii*) are the three most abundant species. Seagrasses are flowering plants that spread through the growth of roots and rhizomes. Seagrasses act to trap and stabilize sediments, reduce shoreline erosion, and buffer coral reefs; they provide food for fish, sea turtles (heavy grazers), conch, and urchins; they provide shelter and habitat for many adult species and numerous juvenile species who rely on the seagrass beds as nursery areas; and they provide attachment surfaces for calcareous algae.

Mangrove habitats are very productive coastal systems that support a wide variety of organisms. The mangrove food web is based largely on the release of nutrients from the decomposition of mangrove leaves, and in part on the trapping of terrestrial material. Red mangroves (*Rhizophora mangle*), with their distinctive aerial prop roots, grow along the shoreline, often in mono-specific stands. The roots of the red mangroves help to trap sediments and pollutants associated with terrestrial runoff and help to buffer the shore from storm waves. Red mangrove forests support a diverse community of sponges, tunicates, algae, larvae, and corals, as well as juvenile and adult fish andshellfish. Black mangroves (*Aveicennia germinans*) and white mangroves (*Laguncularia racemosa*) grow landward of the red mangroves. They also act as important sediment traps. Exposed and sheltered mangrove shorelines are common throughout the U.S. Caribbean.

Throughout the U.S. Caribbean, both rocky shores and sandy beaches are common. While many of these beaches are high-energy and extremely dynamic, buffering by reefs and seagrasses allows some salt-tolerant plants to colonize the beach periphery. Birds, sea turtles, crabs, clams, worms, and urchins use the intertidal areas.

Salt ponds, common in the U.S. Virgin Islands, are formed when mangroves or fringing coral reefs grow or storm debris is deposited, effectively isolating a portion of a bay. The resulting "pond" undergoes significant fluctuations of salinity with changes in relative evaporation and runoff. The biota associated with salt ponds, are, therefore very specialized, and usually somewhat limited. Salt ponds are extremely important in trapping terrestrial sediments before they reach the coastal waters.

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